This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

The scales of the Afri
Stanford University Libraries
3 6105 046 404 500

STANFORD UNIVERSITY
LIBRARIES

SMITHSONIAN

MISCELLANEOUS COLLECTIONS

VOL. 56

"EVERY MAN IS A VALUABLE MEMBER OF SOCIETY WHO, BY HIS OBSERVATIONS, RESEARCHES, AND EXPERIMENTS, PROCURES KNOWLEDGE FOR MEN"—SMITHSON

(PUBLICATION 2091)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
1912

187073

ADVERTISEMENT

The present series, entitled "Smithsonian Miscellaneous Collections," is intended to embrace all the publications issued directly by the Smithsonian Institution in octavo form; those in quarto constituting the "Smithsonian Contributions to Knowledge." The quarto series includes memoirs, embracing the records of extended original investigations and researches, resulting in what are believed to be new truths, and constituting positive additions to the sum of human knowledge. The octavo series is designed to contain reports on the present state of our knowledge of particular branches of science; instructions for collecting and digesting facts and materials for research; lists and synopses of species of the organic and inorganic world; reports of explorations; aids to bibliographical investigations, etc., generally prepared at the express request of the Institution, and at its expense.

In the Smithsonian Contributions to Knowledge, as well as in the present series, each article is separately paged. The actual date of its publication is that given on its special title-page, and not that of the volume in which it is placed. In many cases works have been published and largely distributed, years before their combination into volumes.

CHAS. D. WALCOTT,
Secretary of the Smithsonian Institution.

CONTENTS

1. Cockerell, T. D. A. The scales of the African characinid fishes. Published May 7, 1910. 10 pp., 2 pls. (Publication number 1929.)
2. Hollister, N. Mammals collected by John Jay White in British East Africa. March 31, 1910. 12 pp., 2 pls. (Pub. No. 1930.)
3. Cockerell, T. D. A. The scales of the mormyrid fishes, with remarks on Albula and Elops. May 7, 1910. 4 pp. (Pub. No. 1931.)
4. Schmitter, Ferdinand. Upper Yukon native customs and folklore. May 26, 1910. 30 pp. (Pub. No. 1933.)
5. Clarke, Frank Wigglesworth. A preliminary study of chemical denudation. June 29, 1910. 19 pp. (Pub. No. 1935.)
6. Becker, George F. The age of the earth. June 29, 1910. 28 pp. (Pub. No. 1936.)
7. Elliot, D. G. Description of a new subspecies of African monkey of the genus Cercopithecus. June 11, 1910. 1 p. (Pub. No. 1937.)
8. Busck, August. Notes on a horn-feeding lepidopterous larva from Africa. July 28, 1910. 2 pp., 2 pls. (Pub. No. 1941.)
9. Heller, Edmund. Descriptions of seven new species of East African mammals. July 22, 1910. 5 pp., 3 pls. (Pub. No. 1942.)
10. Dall, William Healey. New land shells from the Smithsonian African Expedition. July 22, 1910. 3 pp. (Pub. No. 1945.)
11. Reese, Albert M. Development of the digestive canal of the American alligator. October 29, 1910. 25 pp., 15 pls. (Pub. No. 1946.)
12. Ritter, Wolfgang. Hodgkins Fund. The flying apparatus of the blow-fly. A contribution to the morphology and physiology of the organs of flight in insects. May 11, 1911. 76 pp., 20 pls. (Pub. No. 1947.)
13. Hollister, N. Two new African ratels. October 10, 1910. 3 pp. (Pub. No. 1988.)
14. Mearns, Edgar A. Descriptions of ten new African birds. December 23, 1910. 7 pp. (Pub. No. 2003.)

15. HELLER, EDMUND. New species of insectivores from British East Africa, Uganda, and the Sudan. December 23, 1910. 8 pp., 1 pl. (Pub. No. 2004.)
16. HRDLIČKA, ALEŠ. Some results of recent anthropological exploration in Peru. April 26, 1911. 16 pp., 4 pls. (Pub. No. 2005.)
17. HELLER, EDMUND. New species of rodents and carnivores from Equatorial Africa. February 28, 1911. 16 pp. (Pub. No. 2006.)
18. STEARNS, MARY R. Bibliography of the scientific writings of R. E. C. Stearns. With biographical sketch by William Healey Dall. April 11, 1911. 15 pp., 1 pl. (Pub. No. 2007.)
19. ABBOT, C. G. The silver disk pyrheliometer. March 31, 1911. 10 pp., 1 pl. (Pub. No. 2008.)
20. MEARNS, EDGAR A. Descriptions of fifteen new African birds. April 17, 1911. 11 pp. (Pub. No. 2010.)
21. NELSON, E. W. Description of a new genus and species of humming bird from Panama. July 8, 1911. 2 pp. (Pub. No. 2015.)
22. NELSON, E. W. Two new subspecies of birds from Panama. September 7, 1911. 1 p. (Pub. No. 2053.)
23. CHRIST, H. On Psomiocarpa, a neglected genus of ferns. November 21, 1911. 4 pp., 1 pl. (Pub. No. 2054.)
24. MAXON, WILLIAM R. A remarkable new fern from Panama. November 22, 1911. 5 pp., 3 pls. (Pub. No. 2055.)
25. MEARNS, EDGAR A. Descriptions of seven new African grass-warblers of the genus Cisticola. November 23, 1911. 6 pp. (Pub. No. 2056.)
26. HOLLISTER, N. Four new mammals from the Canadian Rockies. December 5, 1911. 4 pp. (Pub. No. 2062.)
27. GOLDMAN, E. A. A new kingfisher from Panama. December 1, 1911. 2 pp. (Pub. No. 2058.)
28. MEARNS, EDGAR A. Description of a new species of sunbird, Helionympha raineyi, from British East Africa. November 28, 1911. 1 p. (Pub. No. 2059.)
29. MAXON, WILLIAM R. Three new club-mosses from Panama. January 6, 1912. 4 pp., 3 pls. (Pub. No. 2064.)
30. BENT, A. C. A new subspecies of Ptarmigan from the Aleutian Islands. January 6, 1912. 2 pp. (Pub. No. 2066.)
31. WILLIS, BAILEY. Report on an investigation of the geological structure of the Alps. February 7, 1912. 13 pp. (Pub. No. 2067.)

GENERAL BOOKBINDING CO.
77 578ST 53 005 S 1 AD N4129
QUALITY CONTROL MARK

32. BENT, A. C. Notes on birds observed during a brief visit to the Aleutian Islands and Bering Sea in 1911. February 12, 1912. 29 pp. (Pub. No. 2068.)
33. STANDLEY, PAUL C. Three new plants from Alberta. February 7, 1912. 3 pp. (Pub. No. 2069.)
34. STANDLEY, PAUL C. A new leather flower from Illinois. February 7, 1912. 3 pp., 1 pl. (Pub. No. 2070.)
35. HOLLISTER, N. New mammals from Canada, Alaska, and Kamchatka. February 7, 1912. 8 pp., 3 pls. (Pub. No. 2072.)
36. GOLDMAN, E. A. Descriptions of twelve new species and subspecies of mammals from Panama. February 19, 1912. 11 pp. (Pub. No. 2073.)
37. NELSON, E. W. Descriptions of two new species of nun birds from Panama. February 16, 1912. 2 pp. (Pub. No. 2074.)

SMITHSONIAN MISCELLANEOUS COLLECTIONS

VOLUME 56, NUMBER 1

THE SCALES OF THE AFRICAN CHARACINID FISHES

WITH TWO PLATES

BY

T. D. A. COCKERELL

University of Colorado, Boulder, Colo.

(PUBLICATION 1929)

CITY OF WASHINGTON

PUBLISHED BY THE SMITHSONIAN INSTITUTION

May 7, 1910

WASHINGTON, D. C.
PRESS OF JUDD & DETWEILER, INC.
1910

THE SCALES OF THE AFRICAN CHARACINID FISHES

By T. D. A. COCKERELL

University of Colorado, Boulder, Colo.

(With Two Plates)

As primitive relatives of the Cyprinidæ, confined to the Neotropical and Ethiopian regions, the Characinidæ (or Characidæ) are of more than usual interest to students of the evolution of fishes. After having spent much time in the investigation of the scales of the Cyprinids, I was very anxious to see those of the Characinids, and the opportunity was offered during a recent visit to the British Museum. For all the material used in the preparation of the present paper I am indebted to the kindness of Dr. G. A. Boulenger, who has in his custody at the British Museum a truly wonderful collection of African freshwater fishes, as every ichthyologist knows. It was an extraordinary privilege to have access to these rich materials, which had been gathered with so much difficulty and sometimes danger, and had formed the basis of classical researches.

The sculpture of an ordinary fish-scale includes two important elements, the circuli and the radii. The circuli are circular lines, sometimes referred to as "lines of growth," while the radii are lines or grooves radiating outward from the nuclear area, which may or may not be in the center of the scale, but is practically always in the middle line. The most primitive fish with scales resembling those of the Teleosts is *Amia calva,* and through the kindness of Dr. B. W. Evermann I have been able to examine specimens of this fish from the Yellow River at Plymouth, Indiana. There are no radii, but the scales are made up of longitudinal strands which are really separable elements, and will fray out basally. These appear on the scale as very fine striæ which in the apical field are directed toward a broad rugulose nuclear area. There is no doubt, I think, that these are the circuli of the Teleosts, and indeed they are nearly repeated in various forms, though I know no scale which as a whole can be said to closely resemble that of *Amia.*[1] This view

[1] I placed a scale of *Polypterus endlicheri* (from the White Nile) in acid to ascertain the structure of the organic basis, which proved to be rather scanty and of a sponge-like consistency.

suggests the probability that the Teleosts with very fine and dense circuli (*e. g.*, the majority of the Old World Cyprinids) are so far more primitive than those in which the circuli are fewer (*e. g.*, the New World Cyprinids, but *not* the Catostomids), as had already been assumed on other grounds.

The radii, according to this theory, are of secondary origin. In some cases they may lose their radial arrangement, and more or less simulate circuli. This is seen in *Alosa sapidissima* Wilson (fig. 1), the circuli of which are extremely fine and delicate, while the radii of the basal field actually take the form of widely spaced transverse, almost concentric lines. In some of the scales (the larger and broader ones) this development is so complete as to conceal its origin, but in other scales on the same fish the various transitional states can be perceived.

FIG. 1. *Alosa sapidissima* Wilson
Drawn by Miss E. V. Moore

On the other hand the circuli may also become transverse, losing the appearance of concentric lines. This is excellently shown in *Scomber chrysozonus*, from Massauah (pl. 1, fig. 1); that the lines really are circuli is proved by the scale of *Scomber pneumatophorus* (Table Bay, Cape of Good Hope), (pl. 1, fig. 2), in which they are still obviously circuli.

The African Characinidæ have scales of two main types, which seem to be wholly distinct. The first, including the Hydrocyoninæ and Citharininæ, may be called the Cyprinoid type, showing a distinct—often strong—resemblance to the scales of the Cyprinidæ. In this type the nuclear area is central, or nearly so, and the scales are usually cycloid, rarely ctenoid, and when so not at all like the ctenoid scales of the other group.

The second or ctenoid group proper includes the Ichthyoborinæ and Distichodontinæ, which cannot be separated on the squamation. In this series the apical teeth are very regular and numerous, united laterally, and the nuclear area is almost at the apex, the base being thrown more or less into folds. This basal folding appears to lead to the very distinctive system of basal radii found in the Acanthopterygian and allied fishes; *e. g.*, in *Tilapia nilotica* (Cichlidæ), (pl. 1, fig. 3), *Apomotis cyanellus* (Centrarchidæ), *Cyprinodon fasciatus* (Cyprinodontidæ), and *Anabas munii* (Anabantidæ).

This type of basal radii thus runs through the Haplomi, Acanthopterygii and Percesoces; yet it is wholly absent in the Scombrids, so far as I know, and *Gadus* (*cf.* H. W. Marett Tims, Quart. Journ. Micr. Science, Oct., 1905) shows nothing of it. (The scale of *Gadus* is curiously like that of *Catostomus*.) The ctenoid features found in *Anabas* seem to be traceable to a Berycid source. It is evident, of course, that no Acanthopterygian fish can be derived from any Characinid stock, but it is suggested that the basal folding was developed among the Malacopterygians (*Alosa* shows it sufficiently well) and carried thence to the Characinid and Acanthopterygian (or Haplomid) ancestors.

I hope in some later contribution to compare the South American Characinid scales with the African. At present I cannot do this for lack of material, but the little I know suggests that there may be little resemblance between them. (Figure 2 (drawn by Miss Evelyn V. Moore) shows the scale of *Cheirodon insignis* Steindachner from Panama; this fish is placed by Boulenger in the Hydrocyoninæ, but it will be seen that there is no resemblance to the scales of any of the African members of that subfamily. The scale of *Luciocharax* is quite unlike anything African, but this belongs to an exclusively American subfamily (Xiphostominæ).

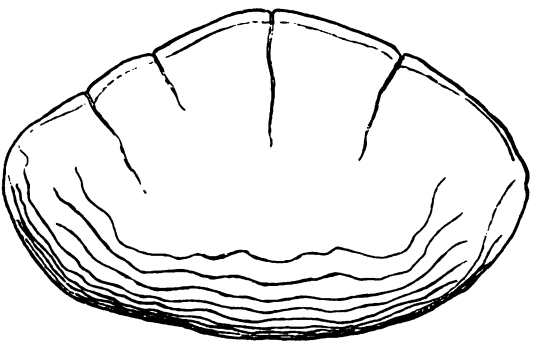


FIG. 2. *Cheirodon insignis* Steindachner

For the means of obtaining the photographic figures (the work of Mr. T. C. Black, of Boulder, Colorado) I am indebted to a grant from the American Association for the Advancement of Science. It may be worth while to state that in order to get good photographs the scales must be mounted dry. When placed in balsam many of the characters are obscured.

HYDROCYONINÆ

The scales of the African Hydrocyoninæ fall naturally into three groups:

(1) *Sarcodaces* group, in which the approximately circular scales have fine and rather numerous radii, and the circular sculpture is very distinct, the apical circuli very coarse and quite different from the basal and lateral. *S. odoë* examined.

(2) *Alestes* group, including *Alestes, Micralestes,* and *Petersius,* in which the radii are few but very strong, the sculpture is often weak in the apical region, and the scales are frequently much broader than long.

(3) *Hydrocyon* group, in which the apical field is more or less rugose, and the radii are evanescent, the basal radii usually absent. The dorsal scales of *Hydrocyon* show numerous but very weak apical radii, which produce some crenulation of the very thin margin, indicating a slight approach to a ctenoid condition. *H. forskalii* examined.

It appears probable that *Sarcodaces odoë* (River Benue, north of Ibi, *H. L. N. Traill*) has the more primitive type of scale. *Hydrocyon forskalii* (River Nile) can be derived from this by the general weakening of all the structures; while the *Alestes* group represents a reduction of the radial system, with a much stronger development of what remains. Thus three fairly distinct tribes would appear to be indicated: Sarcodacini, Alestini, and Hydrocyonini, their typical genera *Sarcodaces, Alestes,* and *Hydrocyon* respectively. The term Hydrocyonini was used by Bonaparte as early as 1838 (Nuovi Annali delle Sci. Nat. 2, p. 132). *Bryconæthiops* I have not seen.

Alestes

Group A. Scales very large, the transverse diameter over 15 mm.

(1) Scales very much broader than long.

Alestes tæniurus Günther. Kribi River, Cameroon (*G. L. Bates*).

Scale about 10.5 mm. long and 16.5 broad; basal radii about 12; discal region divided into many polygonal areas.

(2) Scales not much broader than long.

Alestes rhodopleura Boulenger. Mtondwe Bay, Lake Tanganyika (*Cunnington*).

Scale about 18 mm. long and 21 broad; basal radii two; lateral radii two on each side, more or less inclined to be divided or delta-like marginally; apical radii few and quite irregular; apical region rugose; circuli of basal region extremely fine.

Alestes macrolepidotus Cuvier and Valenciennes. River Nile. Structure essentially as in *A. rhodopleura;* rugosity of apical region, resulting from modified circuli, very pronounced. The discal region may be reticulate.

Group B. Scales smaller, the transverse diameter much less than 15 mm.

Owing to individual variation and the small amount of material available it is impossible to determine the precise specific characters in this group. Some of the species probably cannot be separated on the scales. In no case are the scales of the very broad *tæniurus* type.

(1) Comparatively large reddish scales, with the apical rugosity poorly developed.

Alestes macrophthalmus Günther. Lake Tanganyika (*J. E. S. Moore*).

Radii very few and feeble, in the single scale examined there is only one basal; scale about 7.5 mm. long and 9 broad.

Alestes liebrechtsii Boulenger. Coquilhatville, Upper Congo (*Delhez*).

Radii more numerous, about six basal, but two of these incomplete; discal region with some polygonal areas; scale about 8.5 mm. long and 10.5 broad. The characters separating these two are doubtless variable.

(2) Rather large white scales, with the apical circuli forming conspicuous strong ridges; the basal circuli, as usual, very fine.

Alestes affinis Günther. Wabbi System (*O. Neumann*).

Only one basal radius; apical region with the radii branching and anastomosing quite irregularly, all very strong; scale about 7 mm. long and 8 broad.

Alestes imberi Peters. Lake Nyassa (*Capt. E. L. Rhoades*).

Thinner scales than those of *A. affinis;* basal radii three; apical region quite as in *A. affinis.* Scale about as broad as long.

(3) Rather small (6 to 7 mm. diameter) whitish scales of a rather broad type, having the outline of a little more than a half circle; apical sculpture feeble; basal radii three or four. There is no sign of the apical structure described under *A. affinis.* These scales are certainly nearer to the *macrophthalmus* group than to the *affinis* group.

Alestes (*Brachyalestes*) *longipinnis* Steindachner. Sette Cama, Gaboon (*Gerrard*).

Alestes chaperi Sauvage. Kotchwah River (*R. B. N. Walker*).

These two were united by Günther, and certainly there is no difference in the scales.

(4) Small scales about 6 mm. diameter or less, without very marked characters.

Alestes sadleri Boulenger. Entebbe, Lake Victoria (*Degen*).

Polygonal areas present or absent; apical circuli rather strong.

Alestes lateralis Boulenger. Kafue River, Upper Zambesi (*T. Codrington*).

Scale small, but not from a fully-grown fish. Only one basal radius.

Alestes intermedius Boulenger. Kribi River, Cameroon (*G. L. Bates*).

Scale rather broad, with five basal radii; apical sculpture very feeble; lateral circuli, especially in the subdiscal region, much less dense than usual, and minutely wavy or zigzag.

Alestes nurse Rüppel. River Nile.

Basal radii variable up to about six; polygonal areas present or absent.

Alestes baremose Joannis. River Nile.

Basal radii one or two; polygonal areas not observed; scale in general similar to that of *A. nurse,* but differing in important details, as shown below.

The scales described above were all taken from the vicinity of the lateral line, about the level of the beginning of the dorsal fin. The following notes describe the variation observed on the different parts of the fish.

Alestes macrolepidotus. This species is remarkable for the very large scales, and the posterior situation of the first dorsal fin. The borders of the scales are beautifully purplish-iridescent, but the fish is not silvery like *A. nurse* and *baremose.* The coarse apical circuli become entirely longitudinal, suggesting the corresponding structures in *Amia calva,* in which the progenitors of the circuli are longitudinal strands. The apical radii largely anastomose transversely, resulting in the formation of very irregular transverse markings, few in number. In the ventral region the sculpture is more profuse, and the apical field develops a sort of cancellation, in which the ***longitudinal*** lines appear to represent modified circuli, and the ***transverse*** modified radii. The anterior dorsal scales are again quite different, with

a curiously *Amia*-like sculpture, composed almost altogether of elements representing the circuli, but consisting of coarse longitudinal striæ or strands, which are, however, continuous with the usual extremely fine and regular circuli of the concealed portion of the scales, the latter having about three strong basal radii and one on each side.

Alestes nurse. Very similar in appearance to *A. baremose,* but deeper-bodied. The strong apical circuli are mainly longitudinal, meeting at an acute angle in the middle line. The apical radii often have transverse branches, more or less in the manner of a spreading tree; usually there is a single apical radius, with branches leaving at right angles, but in the dorsal and ventral regions there are more.

Alestes baremose. The sculpture, on close comparison, is really very distinct from that of *A. nurse.* The apical circuli, instead of forming regular grooves, are evanescent, reduced to a fine rugosity; the apical field is sparsely punctate; the one to three apical radii are usually incomplete, and show no lateral branches. The ventral and dorsal scales show many thin, weak, parallel apical radii.

Alestes opisthotænia Boulenger, from Efulen, Cameroon (*G. L. Bates*) has rather large (about 8 mm. long and 10 broad) white scales, resembling those of the *affinis* group; with four basal radii, discal polygonal areas, and coarse apical circuli. The interesting feature of the scale is, however, that it is subctenoid, with small but very evident apical denticulations. The teeth are broader than long, and indicate the beginning of such structures as are found, much better developed and much reduced in number, in *Citharidium ansorgii.* The ctenoid scales of *Distichodus, Xenocharax,* etc., are entirely different. There are *slight* indications of apical denticulation in some other *Alestes,* as *A. rhodopleura* and *A. imberi.*

Micralestes

The scales of this genus cannot be distinguished from those of *Alestes;* that is to say, there is no *generic* difference, though *specific* distinctions may be found to separate any particular species of *Micralestes* from any particular *Alestes.* The scales are always conspicuously broader than long.

Group A. Apical circuli strong, coarse, and complete, those of the two sides meeting at an obtuse angle.

Micralestes holargyreus Günther. Boma (*Delhez*).

Scale 3.5 mm. long, 5.33 broad; six radii, all strong and complete, one apical, one basal, and two on each side; no polygonal areas. In *Alestes* it comes near to *A. longipinnis,* but it is a shorter scale, with much better developed apical sculpture.

Group B. Apical sculpture feeble, the circuli ill-defined, although the basal circuli are very distinct.

Micralestes altus Boulenger. Lindi, Congo (*Brussels Museum*).

Scale about 5 mm. long and 7 broad; basal circuli much denser than lateral; three basal radii, one apical, one or two on each side; no polygonal areas. (These characters will vary; I doubt whether there is any constant difference in the radii between the species of *Micralestes.*)

Micralestes humilis Boulenger. Ja River, S. Cameroon (*G. L. Bates*).

Scale about 4 mm. long and 5.33 broad; structure as in the last. Basal radii one to six; apical one to two; polygonal areas present or absent.

Micralestes interruptus Boulenger. Stanley Pool. Congo Free State.

Scale small, only about 3.33 mm. wide; structure as in the others, but basal circuli less dense. Five basal and three apical radii; polygonal areas present.

None of the *Micralestes* show any branching of the apical radii.

Petersius

The scales of *Petersius* are quite as in *Micralestes*, having the same broad form, with few radii, the apical never branching.

Group A. Scale relatively large, about 6 mm. long and 9 broad; apical sculpture very feeble.

Petersius major Boulenger. Nyong River, Cameroon (*G. L. Bates.*)

Basal radii four, apical two.

Group B. Scale smaller, diameter about 5 mm. or rather less. Apical circuli better developed.

Petersius occidentalis Günther. Infoan (*Walker*).

Basal radii about four, variable; sides of scale flatter than in the next.

Petersius hilgendorfi Boulenger. Kutu, Lake Leopold II (*Delhez*).

The scale examined has only four radii, one basal. Its outline is that of a half circle.

Petersius caudalis Boulenger. Boma (*Delhez*).

Basal radii two or three; small polygonal areas sometimes developed. The smallest of the *Petersius* scales.

CITHARININÆ

Herbivorous fishes, with the teeth minute or absent. Gill (Proc. U. S. Nat. Mus. 18, p. 207) suggests that this group should perhaps constitute a distinct family, Citharinidæ. The scales are subcircular to transversely oval, *without basal radii*, wherein they differ from the African Hydrocyoninæ, excepting *Hydrocyon*.

The following table separates the scales of the species studied:

Scales ctenoid, with large, sharp apical teeth, but these few and far apart, wholly unlike those of *Distichodus*, etc.; nuclear area nearly central, and with circuli to middle; circuli very strong, only moderately dense; scales about 2.33 mm. long and 3.67 broad.. ..*Citharidium ansorgii* Boulenger, Lake Oguta, Nigeria (*Ansorge*).

Scales cycloid 1

1. Apical area with fewer and coarser circuli, abruptly marked off from lateral 2

Apical area not, or not very abruptly, marked off from lateral..... 4

2. Broad scale with very many apical radii; nuclear area granular; scale about 7 mm. long and 10 broad, the largest of the Citharinine scales.....*Citharinus gibbosus* Boulenger. Niamkolo, Lake Tanganyika (*Cunnington*).

Rounder scales, with fewer apical radii; nuclear area with circuli to middle 3

3. Scale larger, nearly 6 mm. long, about 7 broad; character of sculpture entirely as in *C. gibbosus*.....*Citharinus macrolepis* Boulenger. Boma, Lower Congo (*Delhez*).

Scale smaller, about 5 mm. broad; otherwise practically the same.. ..*Citharinus latus* Müller and Troschel. Beni Souef (*Loat*).

4. Nuclear area with circuli to middle; apical area with very large, coarse circuli, but not quite abruptly separated from lateral; scales small, a little over 3 mm. wide....*Citharinus citharus* Geoffroy (*geoffroyi* Cuvier). White Nile (lake near) (*Loat*).

Nuclear area broadly granular; apical circuli coarse; scale 4.33 mm. broad.. ..*Citharinus congicus* Boulenger. Bolobo, Congo (*Grenfell*).

The above key is not wholly satisfactory, because the scales of *Citharinus* are really of a very uniform type, without very obvious specific characters. Two tribes are indicated: Citharidiini for *Citharidium,* and Citharinini for *Citharinus.*

Boulenger places two American genera in this subfamily, but Gill separates them as Curimatinæ. I have not seen their scales.

Hydrocyon forskalii runs in the above table near *Citharinus congicus,* but the resemblance is merely superficial.

ICHTHYOBORINÆ

Carnivorous forms with ctenoid scales. There is nothing to distinguish their scales from those of the Distichodontinæ. The apical teeth are numerous and close together, having little in common with those of *Citharidium.* The species examined are:

Phago boulengeri Schilthuis. Monsembe, Upper Congo (*J. H. Weeks*).
The scales are hard, bone-like plates joined together, but the apical densely-set spine-like teeth are quite as in the other forms.

Eugnathichthys eetveldii Boulenger. Monsembe, Upper Congo (*J. H. Weeks*).
Small subquadrate scales, with the nucleus apical, just below the row of teeth; no radii, but the basal region is broadly plicate.

Ichthyoborus besse Joannis. Fashoda (*Loat*).
Scales practically as in the last.

Neoborus ornatus Boulenger. Monsembe, Upper Congo (*J. H. Weeks*).
Scales also as in *Eugnathichthys,* except that the apical region is coarsely rugose.

Paraphago and *Mesoborus* have not been examined.

DISTICHODONTINÆ

Herbivorous (or partly herbivorous) fishes with ctenoid scales, which resemble those of the Ichthyoborini. The fact that *Eugnathichthys* and *Ichthyoborus* have quite similar scales, and the absence of any characteristic difference between the scales of the Ichthyoborine and Distichodontine fishes, show that after the development of this type of squamation differentiation took other directions; hence the scales fail to afford any adequate clue to the minor subdivisions of these groups.

In some *Distichodus* (*notospilus, sexfasciatus, atroventralis, engycephalus*) the subapical (exposed) part of the scale is more or less grooved or subreticulate, but otherwise there are no substantial differences between the genera and species examined, which are as follows:

Nannocharax fasciatus Günther. Kribi River, Cameroon (*Bates*).

Nannocharax niloticus Joannis. River Nile.

The *Nannocharax* scales are the smallest of the series, less than 2 mm. broad. This accords with the small size of the fishes.

Neolebias unifasciatus Steindachner. Ja River, Cameroon (*Bates*).

Scales about 2.33 mm. broad.

Nannæthiops unitæniatus Günther. Sette Cama, Gaboon (*Gerrard*).

Scales about 4 mm. broad; basal plication very strong. The scales are longer in proportion to their breadth than those of *Neolebias*.

Xenocharax spilurus Günther. Ibali, Lake Leopold II (*Delhez*).

Scales about 4.25 mm. long and 5 broad.

Distichodus antonii Schilthuis. Monsembe, Upper Congo (*Weeks*).

In this species and *D. atroventralis* the scale is unusually broad in proportion to its length.

Distichodus atroventralis Boulenger. Kutu, Lake Leopold II (*Delhez*).

I do not know how to distinguish the scale definitely from that of *D. antonii*.

Distichodus engycephalus Günther. River Nile at Cairo (*Loat*).

Scales not quite 5 mm. long, about 6 broad; apical (exposed) area reticulate.

Distichodus fasciolatus Boulenger. Monsembe, Upper Congo (*Weeks*).

Scales about 3 mm. broad; nuclear area more or less rugose.

Distichodus brevipinnis Günther. Fashoda, White Nile (*Loat*).

Scales little broader than long, shaped as in *D. niloticus*, but larger.

Distichodus niloticus Linnæus. Fashoda, White Nile (*Loat*).

Distichodus rostratus Günther. Gondokoro, White Nile (*Loat*).

Scales quite as in *D. niloticus;* dermal pigment-spots also the same.

Distichodus lusosso Schilthuis. Banzyville, Ubangi (*Capt. Royaux*).

Scales small, less than 3 mm. diameter; subapical field broadly rugulose.

Distichodus mossambicus Peters. Loangwa River, N. W. Rhodesia (*S. A. Neave*).

Nuclear area very broadly rugulose; a subdorsal scale is broader in proportion to its length than one from near the lateral line.

Distichodus sexfasciatus Boulenger. Coquilhatville, Upper Congo (*Delhez*).

Scale rather broad; apical field with radiating grooves.

Distichodus notospilus Günther. Kribi River, Cameroon (*G. L. Bates*); Komadekke, Ogowe (*W. J. Ansorge*).

The Kribi R. specimen has the largest scales I have seen in this genus, about 8.5 mm. long and 10.5 broad.

Judging from the general characters of the fishes, and especially perhaps from the development of the maxillary, we may infer that the Hydrocyoninæ, a carnivorous group, have given rise to the herbivorous Citharininæ. Using similar criteria, however, it would seem that the herbivorous Distichodontinæ had given rise to the carnivorous Ichthyoborinæ.

EXPLANATION OF PLATES

PLATE 1.

FIG. 1. *Scomber chrysozonus.* Massauah. British Museum. Gill rakers very long.

FIG. 2. *Scomber pneumatophorus.* Table Bay, Cape of Good Hope. = *colias* = *japonicus.* British Museum.

FIG. 3. *Tilapia nilotica.* Birket Karûn, Fayoum. British Museum.

FIG. 4. *Alestes sadleri.* Entebbe. Lake Victoria (Degen). British Museum.

FIG. 5. *Micralestes holargyreus* Günther. Boma (Delhez). British Museum.

FIG. 6. *Petersius caudalis.* Boma (Delhez). British Museum.

PLATE 2.

FIG. 1. *Citharidium ansorgii.* Lake Oguta. S. Nigeria (Ansorge). British Museum.

FIG. 2. *Citharinus congicus.* Bololo. Congo (Grenfell). British Museum.

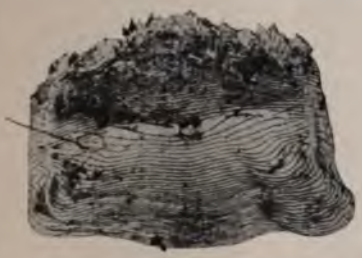
FIG. 3. *Eugnathichthys eetveldii* Blgr. Monsembe. Upper Congo (J. H. Weeks). British Museum.

FIG. 4. *Xenocharax spilurus.* Ibali. Lake Leopold II (Delhez). British Museum.

FIG. 5. *Distichodus antonii.* Monsembe. Upper Congo (Weeks). British Museum.

FIG. 6. *Distichodus sexfasciatus.* Coquilhatville. Upper Congo (Delhez). British Museum.

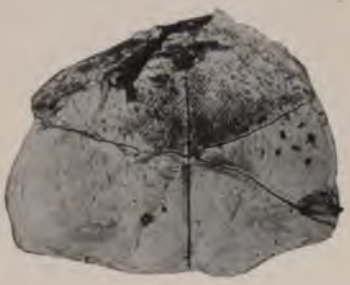
FIG. 7. *Distichodus notospilus.* Komadekke. Ogowe (W. J. Ansorge). British Museum.



1

2

3

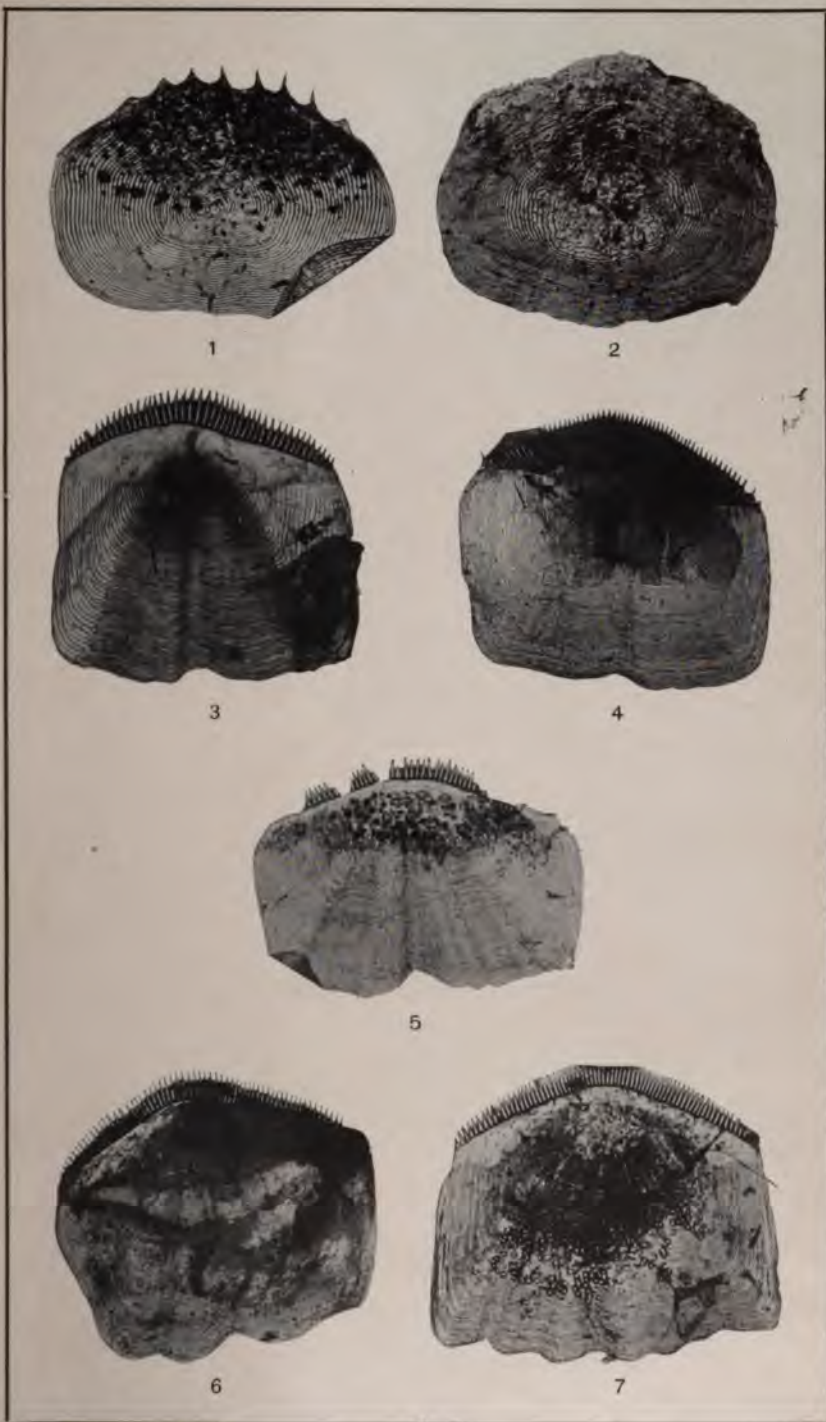


4

5

6

SCALES OF AFRICAN FISHES



SCALES OF AFRICAN FISHES

SMITHSONIAN MISCELLANEOUS COLLECTIONS

VOLUME 56, NUMBER 2

MAMMALS COLLECTED BY JOHN JAY WHITE IN BRITISH EAST AFRICA

WITH TWO PLATES

BY

N. HOLLISTER

Assistant Curator, Division of Mammals, U. S. National Museum

(PUBLICATION 1930)

CITY OF WASHINGTON

PUBLISHED BY THE SMITHSONIAN INSTITUTION

March 31, 1910

MAMMALS COLLECTED BY JOHN JAY WHITE IN BRITISH EAST AFRICA

By N. HOLLISTER

Assistant Curator, Division of Mammals, U. S. National Museum

(With Two Plates)

Mr. John Jay White, of Washington, D. C., has presented to the United States National Museum a number of large mammals collected by himself in British East Africa during the summer of 1908. Several of the specimens are of special interest, and the collection as a whole is of considerable importance.

On May 8, 1908, in company with Dr. W. S. Rainsford, Mr. White left Nairobi for Nakuru, at which point the party left the railroad on the following day and traveled northward, by way of Ravine Station, to Sirgoit Rock, where they arrived May 21. From this date until the first of July the time was spent in hunting over the Guas Ngishu Plateau. July 8 they arrived at Ravine on the return, and traveled east and north for the Laikipia Plateau. About six weeks were spent in hunting over the region to the north of Laikipia Boma and Mount Kenia, and, on the return to the railroad, three days—September 6 to 8—were devoted to the game on the Elmenteita Plains. September 18 the party again left Nairobi, and another month was spent on the Guas Ngishu Plateau.

Mr. White has furnished some interesting information about many of the species. The substance of this is included, throughout the list, after the technical notes on the specimens.

GIRAFFA CAMELOPARDALIS ROTHSCHILDI Lydekker

Body skin and mounted head of an adult male (No. 155438) from the Guas Ngishu Plateau, June 22. This specimen is a topotype and therefore of special value to the Museum. The mizzen horns are only slightly developed .

This animal was almost a record specimen for the form. Measured rather hurriedly in the rain, without the front legs fully stretched, it exceeded seventeen and a half feet in height. The dry skin measured twenty-one and one-half feet from tip of nose to end of tail, and exactly the same distance between the edges of the fore hoofs across the shoulders. Giraffes were found to be fairly plen-

tiful on the Guas Ngishu Plateau, and herds numbering up to a dozen or fifteen animals were frequently seen. One herd of about seventy-five was noted, but this group later divided, about twenty-five animals going in one direction and the remainder in another.

BUBALIS COKEI (Günther)

Skull and skin of head and neck of a large male, given to Mr. White by Dr. W. S. Rainsford. Probably killed on Dr. Rainsford's last trip to the Thika River region, northeast of Nairobi, in December, 1908.

The skull is a remarkable specimen in many ways, and differs from any in the large series before me from neighboring regions to the north and south. Compared with skulls of old males from Taveta, Kapiti Plains, and the Guaso Nyiro River, it differs in its greater length, greater breadth, relatively short distance from anterior end of premaxilla to first premolar, wide interpterygoid space, and small teeth. The horns are massive, wide spreading, and the first ascending section is much longer than in any other specimen. The terminal section is short, and the horn is therefore divided into almost equal thirds, the outward ascending, horizontal, and terminal parts being of equal length. The measurements of this skull (No. 155430) are: Condylobasal length, 410 millimeters; palatal length, 235; greatest breadth, 142; facial length, 405; muzzle to orbit, 302; upper tooth row, 88; length of horns, 390; circumference at base, 254; greatest spread, 430; spread at points, 395; length of backward terminal point, 120.

These animals were noted by Mr. White on the Laikipia Plateau, in the Elmenteita and Naivasha Lake country, and on the Athi and Kapita plains. None were seen on the Guas Ngishu Plateau.

BUBALIS JACKSONI Thomas

Skull and head skin of adult male from the Guas Ngishu Plateau, about June 15. This specimen, from only a short distance north of the type locality of *jacksoni*, agrees with the descriptions of that species, and the specimens in the Museum, in most particulars. The points of the horns, however, incline inward, after the style of *B. niedecki*, from the White Nile region. Another specimen from the same locality, a mounted head in Mr. White's collection, has the horn tips nearly parallel, or but slightly turned outward; and others were killed, as shown in photographs taken by the party, in which the horns distinctly turned outward. This illustrates the instability

of such minor horn characters, as a large series would evidently show considerable variation in the angle of the terminal section of the horn.

The measurements of this skull (No. 155431) are: Condylobasal length, 426 millimeters; palatal length, 241; greatest breadth, 138; facial length, 438; muzzle to orbit, 312; upper tooth row, 100; length of horns, 553; circumference at base, 304; greatest spread, 250; spread at points, 112; length of smooth backward terminal section, 210.

The skin of the head is a rich red in color with a faint stripe of black down the back of the neck from between the ears to the point where it was severed from the body.

This hartebeest was very abundant on the Guas Ngishu Plateau, where hundreds were seen almost daily, in herds of from three or four up to fifty or more each. Many other animals, especially the zebra and topi, and sometimes the giraffe and eland, take advantage of the abundance of the kongoni and graze among the herds, apparently depending upon them to give the first alarm of approaching danger. The breeding season for many of the British East African ungulates appears to extend over the greater part of the year, and, in large herds of Jackson's kongoni, young of several ages, from small calves to nearly grown, were often seen.

CONNOCHÆTES TAURINUS ALBOJUBATUS Thomas

Skin of head and neck to withers. Killed by Dr. Rainsford on the Athi Plains, in December. Practically a topotype of *albojubatus*. The color represents the dark phase and is much darker than in any of six heads in the Museum collection from "Masailand," the yellowish-white throat fringe being especially conspicuous.

This animal was seen only in the Athi Plains country and apparently does not occur on the Laikipia or Guas Ngishu plateaus.

OREOTRAGUS OREOTRAGUS SCHILLINGSI (Neumann)

In the collection presented by Mr. White were the feet of one of these antelopes from the Laikipia Plateau. In his collection of trophies Mr. White has two heads of old bucks which differ greatly in color. One from Elmenteita has the head gray, with almost pure white markings, while the head from the Laikipia country is everywhere deeply suffused with an ochraceous color, giving a very different appearance to the animal.

Klipspringers were frequently seen on the Laikipia Plateau, usually in small groups of two or three individuals. At one time five were seen on the same hill, but this was probably a chance gathering of two lots. None were seen on the Guas Ngishu Plateau.

OUREBIA COTTONI Thomas

PLATE 1, FIG. 1, SKULL

Three skulls and head skins from south of the Nzoia River, on the Guas Ngishu Plateau, June. These are practically topotypes of *cottoni*, described from Sirgoit Rock, and show the species to be very distinct from *O. kenyæ*, from the region northeast of Nairobi, though closely related to *O. montana*. From the latter it is, however, readily distinguished by the larger horns. The skins agree with the series examined by Thomas in the absence of a distinct dark frontal blaze. The skulls agree in all important measurements and characters with the description of the type. They measure:

	155415 Adult male.	155420 Young male	155421 Young male.
	mm.	*mm.*	*mm.*
Greatest length	168	165	163
Condylobasal length	157	155	154
Greatest breadth	75	73	73
Interorbital breadth	54	45	40
Muzzle to orbit	87	85	85
Upper tooth row	53	—[1]	—[1]
Length of horn	123	100	93

[1] Last molars not entirely in place.

OUREBIA MICRODON, new species

PLATE 1, FIGS. 2, 3, SKULL

Type.—Skull of adult male, Cat. No. 155422, U. S. N. M., collected south of the Nzoia River on the Guas Ngishu Plateau, British East Africa, summer of 1908, by John Jay White.

Diagnostic characters.—Size large; rostrum long; teeth small; horns short, stout, and heavily ringed.

Color.—External characters unknown.

Skull and teeth.—Compared with skulls of *O. cottoni* the type skull of *O. microdon* is much larger, with longer rostrum, narrow interpterygoid fossa, and smaller teeth. Though the skull is larger, the teeth are actually smaller. The basioccipital is nearly square, with surface almost flat; very different from the deep-pitted, triangular basioccipital of *O. cottoni*. From *O. montana* it differs in

much larger size; horns stouter and heavily ringed; rostrum heavier; basioccipital square and flat. It may be distinguished from skulls of *O. kenyæ* by its larger size, longer rostrum and nasals, narrow interpterygoid fossa, square and flat basioccipital; and shorter, stouter, more heavily-ringed horns. The skull of *O. microdon* differs also from skulls of all the above-mentioned species in the straight line of the inner edge of the upper tooth row, which in all of these is decidedly concave. The palate, therefore, is almost oblong, and the distance across between the first premolars almost equals the distance across between the last molars.

Measurements.—See table below for measurements of the type skull.

Remarks.—As known from the skull alone this new oribi is very different from *O. cottoni,* inhabiting the same region. It appears to be more closely related to *O. kenyæ,* from the headwaters of the Tana River.

A comparison of measurements of skulls of adult males of the four species of *Ourebia* from the region is given in the following table:

Ourebia skulls. Adult males	*O. microdon.* 155422 Guas Ngishu Plateau. Type.	*O. cottoni.* 155415 Guas Ngishu Plateau.	*O. kenyæ.* 162857 Near Nairobi.	*O. montana.* 112998 120 mi. east of Lado.
	mm.	*mm.*	*mm.*	*mm.*
Greatest length	175	168	165	164
Condylobasal length	163	157	154	153
Basal length	152	146	143	144
Palatal length	98	94	88	89
Greatest breadth	77	75	75	74
Interorbital breadth	51	54	49	44
Muzzle to orbit	95	87	85	86
Length of nasals	60.5	61	51	58
Upper tooth row	48	53	49	50
Length of horn	108	123	115	102
Circumference of horn	55	50	47	47

KOBUS DEFASSA UGANDÆ (Neumann)

Skull and head skin of adult male, killed on the Guas Ngishu Plateau, south of the Nzoia River, summer of 1908. The specimen agrees with Neumann's description in its large size and colors, the bright rufous face contrasting decidedly with the paler color of the cheeks and neck.

Measurements of the skull (No. 155414) are: Greatest length, 420 millimeters; condylobasal length, 408; greatest breadth, 166;

nasals, 153; palatal length, 220; interorbital breadth, 123; upper tooth row, 114; muzzle to orbit, 246; length of horn, 692; circumference of horn at base, 249; distance between points, 420; greatest spread, 507. In this skull the premaxillæ fail to reach the nasal bones by a distance of ten millimeters.

CERVICAPRA REDUNCA WARDI Thomas

Skull and head skin of adult male from the Guas Ngishu Plateau, June. Measurements of skull (No. 155429): Greatest breadth, 103 millimeters; length of nasals, 92; interorbital breadth, 63; upper tooth row, 58; length of horn, 217; distance between points, 135.

The reedbuck was common on the Nzoia River; singles, pairs, and small herds of up to seven or eight animals were seen.

GAZELLA THOMSONI NASALIS Lonnberg

Three skulls of adult males, two of them accompanied by skins of head and neck to shoulders, from Elmenteita, September 7. The skins exhibit a very distinct black patch on the nose, and appear to represent the northern race. The skulls show no appreciable characters to separate them from skulls of typical *thomsoni* from the Kilimanjaro region. Measurements of skulls:

	155427	155428	155426
	mm.	mm.	mm.
Condylobasal length	198	196	183
Greatest breadth	84	88	85
Muzzle to orbit	101	105	98
Length of nasals	54	50	42
Interorbital breadth	49	55	50
Upper tooth row	54	55	57
Length of horn	300	315	281
Distance between points	100	86	104

Very abundant about Elmenteita. Comparatively few were seen on the Laikipia Plateau and none were found on the Guas Ngishu Plateau.

GAZELLA GRANTI GRANTI Brooke

Skulls and head skins of two adult males, killed on the Elmenteita Plains about September 7. Skull measurements are as follows:

	155424	155425
	mm.	*mm.*
Greatest length	115	114
Condylobasal length	264	261
Palatal length	134	132
Muzzle to orbit	141	137
Interorbital breadth	70	65
Upper tooth row	88	85
Length of horn	565	580
Distance between points	290	263

Grant's gazelles were quite plentiful at Elmenteita, though by no means so abundant as the Thomson's gazelles.

GAZELLA GRANTI NOTATA Thomas

Skull and head skin of adult male, shot near the upper waters of the Guaso Nyiro River, on the Laikipia Plateau, July 28.

The general color of the skin of head and neck is much darker than in specimens of *Gazella g. granti* from the Kilimanjaro region. The horns are very different, also, spreading but little at the points and with much less of the graceful gazelle curve of typical *granti*. There appear to be no constant cranial characters by which skulls without horns of the two forms can be separated. Measurements of the skull: Condylobasal length, 260 millimeters; palatal length, 129; greatest breadth, 111; muzzle to orbit, 138; interorbital breadth, 61; upper tooth row, 81; length of horn, 512; distance between points, 160.

This gazelle was seen by the expedition only on the Laikipia Plateau, where it was not especially plentiful.

ORYX ANNECTENS, new species

Type.—Skin, Cat. No. 155436, U. S. N. M., collected in the vicinity of the Guaso Nyiro River, Laikipia Plateau, British East Africa, about August 8, 1908, by John Jay White.

Diagnosis.—In general like *Oryx beisa,* but lateral stripe narrower and head markings somewhat approaching those of *O. callotis;* skull as in *O. beisa,* but molars conspicuously larger, their size nearly as in *O. callotis.*

Color.—The skin differs in color and markings from a Berbera, Somaliland, specimen and all plates and descriptions of the Abyssinian and Somaliland animals. The main body color is an ecru drab with a buffy tint and a decided vinaceous cast. The lateral stripes, which in *beisa* are broad bands about 30 mm. wide in the

middle and about 50 mm. wide near the posterior end, are reduced to narrow streaks from 8 mm. wide in the middle to 10 mm. wide near the posterior end. The stripe is nowhere pure blackish brown, as in *beisa,* but is everywhere mixed with hairs of the body color. In *beisa* the lateral stripe sharply divides the area of color of the side from the white of the belly. In the Laikipia animal the white below the stripe is suffused with the darker color of the side, the stripe really passing across the lower edge of the side color nearly an inch above the white of the belly, which gradually becomes purer below it, instead of being sharply defined. The dorsal stripe is also less distinct.

The markings of the head differ somewhat from a head of *beisa* also. The black stripe passing through the eye extends down and forward nearly to the corner of the mouth, and the face patch is broader at the lower end, the two black areas thus reaching within less than 25 mm. of each other, much after the pattern of coloration in *O. callotis.* In another example, a mounted head in Mr. White's collection, also from Laikipia, the eye stripe passes down to join the black throat stripe. This head, as well as another head skin, accompanied by the skull, presented to the Museum by Mr. White, agrees with the type skin in the general peculiar color.

Skull and teeth.—Skull as in *O. beisa,* but with much larger teeth; molars nearly as broad as long; lacrymal vacuities greater.

From a Taveta specimen of *O. callotis* the skull of this new species differs in many particulars. It is smaller and much narrower in front of orbits. Ends of premaxillæ square, very different from the tapering, pointed ends in *callotis.* Median palatal notch shallow, not reaching to plane of last molars. Upper tooth row much shorter, about equaling the length of last five teeth of *callotis;* molars about as broad as long. Lacrymal capsules much less inflated. Audital bullæ small and flattened; alisphenoids smaller.

Measurements.—The skull of an adult male (No. 155413) from the type locality measures: Condylobasal length, 356 millimeters; greatest breadth, 152; muzzle to orbit, 219; least interorbital breadth, 103; length of nasals, 142; upper tooth row, 105; length of horn, 685; spread at points, 210.

Remarks.—This new oryx apparently needs no special comparison with *O. b. gallarum.* From *O. callotis* it differs in its lack of ear tufts and the position of the parting of the hair on the back. These and other general characters place it in the *beisa* group. The skull differs so greatly from a skull of *O. callotis* that it would cer-

tainly seem that Lydekker[1] was in error when he considered *callotis* a subspecies of *beisa.*

This antelope was first seen soon after leaving Laikipia Boma. It was generally distributed over the Laikipia Plateau and was fairly abundant. Reported as especially plentiful about forty or fifty miles north of Mount Kenia.

TRAGELAPHUS DAMA Neumann

Complete skin of old buck. The tag was lost from this specimen, but it was almost surely killed on the upper Nzoia River. It agrees well with the description of *T. dama,* differing only in the lack of numerous white spots along the sides of the body. As it is well known that the white body spots on bushbucks tend to disappear in males with old age, this specimen can well be called *dama.* This skin has four faint body spots on each side, formed by only a few white hairs each, and a yellowish-white streak in front of each eye. These are about the only characters to distinguish it from the descriptions of *Tragelaphus sylvaticus meruensis* Lönnberg and *Tragelaphus tjaderi* Allen, between which I can find no appreciable difference. It would hardly seem that both of these latter forms are entitled to recognition.

Mr. White tells that the Kikuyu natives explain the presence of the peculiar short-haired collar in this group of bushbucks by a story to the effect that the Great Spirit ties the animals up each night.

BOÖCERUS EURYCERUS ISAACI Thomas

The collection contains two skins of the rare East African bongo. They were purchased from natives at Nairobi, and were supposedly killed in the vicinity of the Mau Escarpment. The skins differ greatly in color and are both quite unlike a mounted bongo in the Museum, also from East Africa.

No. 155435, skin of body, is of a bright, glossy hazel color, shading to dark chestnut and black on the shoulders and chest; a faint black dorsal stripe from withers to rump; twelve white vertical stripes on each side, all but one pair practically meeting on the dorsum; white spots on legs very large. A mounted head in Mr. White's private collection, presumably from this same individual, and which I have had the pleasure of examining, has the face and muzzle all around, from level of the eyes to near the lips and chin,

[1] The Game Animals of Africa, p. 285, 1908.

blackish; forehead dark chestnut red; lips and chin white; eyes encircled with tawny; a broad white face stripe and the two white spots under the eyes greatly enlarged, the upper one twice as long as wide; throat blackish to within eight inches of the white crescent on the lower neck.

No. 155434, complete skin, is of a glossy chestnut bay; neck, chest, and lower sides black; a distinct black dorsal stripe from neck to rump, the hair forming a short, stiff mane to middle of back; eleven white stripes on right side, thirteen on left; face blackish; upper forehead dark chestnut; a broad, dark fawn stripe from eye to end of white streak across face; face streak greatly reduced and divided in center by a blackish chestnut stripe; cheek spots large and irregular in shape.

The mounted specimen in the Museum is of about the same general color tone as No. 155435, from which it differs in lack of blackish on the shoulders, neck, and chest, the body being entirely of the bright, glossy hazel color. This specimen has thirteen vertical stripes.

Thus we have three specimens of the bongo, all from British East Africa, and all differing widely from one another. Not knowing the exact locality in which each was killed, it is useless to speculate on the meaning of these great differences. It is hard to believe that the great variation between the pure hazel-colored specimen and the one with the maximum amount of black is explained by individual variation in the same forest.

TAUROTRAGUS ORYX PATTERSONIANUS Lydekker

Skin of adult male from the Guas Ngishu Plateau, May 17.

Eland, which were greatly reduced in numbers in parts of British East Africa some years ago by the rinderpest, are slowly gaining in numbers. Several herds of from forty to sixty head were seen on the Guas Ngishu Plateau, and one herd of sixty or more animals was found in the Laikipia country.

EQUUS BURCHELLI GRANTI de Winton

Skin from the Guas Ngishu Plateau, about June 15.

Zebras were found in abundance both on the Guas Ngishu and Laikipia plateaus.

FELIS LEO SABAKIENSIS Lönnberg

Body skin and two skulls of adult males from the vicinity of Nairobi. These skulls differ greatly from Abyssinian specimens, and agree in general characters with specimens from the east coast. They differ from skulls of *massaicus* in all the minor particulars mentioned by Dr. Lönnberg, and represent his recently described race. A number of skins in Mr. White's possession vary considerably in color, and the older males show much reddish brown and black in the body color and mane, some being rather dark animals on the whole. The skins of females and young males show faint spotting below.

Measurements of the skulls:

	155442 mm.	155443 mm.
Greatest length	365	373
Zygomatic breadth	241	234
Length of nasals	122	118
Interorbital breadth	70	70
Alveolar diameter upper canine	27.5	26
Length of upper premolar row	77	79.5
Length of upper carnassial	38	39
Length of lower molar-premolar series	74	77
Length of lower carnassial	28.5	29

ERYTHROCEBUS WHITEI, new species

PLATE 2, SKULL

Type.—Skin and skull of adult male, Cat. No. 155340, U. S. N. M., collected on the Nzoia River, Guas Ngishu Plateau, British East Africa, September 30, 1908, by John Jay White.

Diagnostic characters.—Size large; hair of forward part of body long and shaggy, 175 mm. long at shoulders; back and shoulders grizzly cinnamon-rufous; black stripe from nose over eye and backward, forking to crown and ear; crown, rump, and dorsal stripe from middle of back to past root of tail dark, glossy bay; reddish of back extending down hind legs slightly more than half way to knee; fore arm creamy white.

Color of type.—Nose, lips, and cheek beard cream; a black stripe from nose between eyes, turning outward over eyes, back from corner of eye, and forking to crown and ear; crown patch dark chestnut bay; spot in front of ear, nape, and back grizzled cinnamon-rufous; the long hairs of back cinnamon-rufous at roots, shading to bright bay on terminal half, with sub-apical band of buff and tip

of glossy black; shoulders with much more black, giving them a general grizzly appearance, the individual hairs with an extra ring of black. Lower neck and arm-pits white; arms below elbow and hands dirty creamy white. A dark stripe, from middle of back to tip of tail, cinnamon-rufous, richest and darkest on rump and root of tail, where it is pure glossy bay, and shading to pale ochraceous at tip of tail. Rump to callosities and down outer sides of legs slightly more than half way to knees glossy bay; outsides of legs and feet cream; inner sides of legs white; under side of tail cream. Long hair of sides pale cinnamon-rufous, with less black than above; belly thinly haired, the hairs ochraceous to ochraceous-buff with white tips.

Measurements of type.—Length of skin from nose to root of tail, 870 millimeters; length of tail (dry skin), 640. Skull: Greatest length, 149; condylobasal length, 120; zygomatic breadth, 99; length of nasals, 22.5; maxillary tooth row, exclusive of canines, 32.

Erythrocebus whitei seems to be a very different animal from any of the previously described species. It differs from the plate of the type specimen of *E. pyrrhonotus*[1] in its grizzled back and shoulders, black lines over eye to ears and crown, dark bay frontal patch, and restricted markings on legs. From *E. formosus* it differs in the black brow line extending between eye and ear; hair of lower rump and back not yellow tipped, but black tipped, giving the whole back a very different color—cinnamon-rufous mixed with black, instead of yellowish; sides of neck and chest and outer sides of arms not lemon yellow. From *E. baumstarki* it may be distinguished by the general body color, dark grizzled cinnamon-rufous, instead of pale light red; distinct black forehead band and no white between eye and ear, and many other characters.

Several small groups of these red monkeys were seen on the Guas Ngishu Plateau, in the neighborhood of the Nzoia River. Two specimens were killed by the party; both single males shot from low trees. As usually seen, they were in parties of three or four to a dozen animals, traveling on the ground in open country, and were very hard to approach.

[1] Geoffroy-St. Hilaire and Cuvier, Histoire Naturelle des Mammifères, Tome 7, 1842.

1. OUREBIA COTTONI Thomas

2, 3. OUREBIA MICRODON, NEW SPECIES. TYPE

Reduced about one-half

ERYTHROCEBUS WHITEI, NEW SPECIES. TYPE

Reduced about one-half

SMITHSONIAN MISCELLANEOUS COLLECTIONS

VOLUME 56, NUMBER 3

THE SCALES OF THE MORMYRID FISHES

WITH

REMARKS ON ALBULA AND ELOPS

BY

T. D. A. COCKERELL
University of Colorado, Boulder, Colo.

(PUBLICATION 1931)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
May 7, 1910

WASHINGTON, D. C.
PRESS OF JUDD & DETWEILER, INC.
1910

THE SCALES OF THE MORMYRID FISHES, WITH REMARKS ON ALBULA AND ELOPS

By T. D. A. COCKERELL

University of Colorado, Boulder, Colo.

The Mormyridæ constitute a remarkable family of Malacopterygian fishes confined to Africa. The brain is of unusual size and the shape of the head is peculiar, in some forms being produced into a long snout, reminding one of an ant-eater. The Nile system is rich in these fishes, having no fewer than seven genera, as follows: *Mormyrops* (one species), *Petrocephalus* (4), *Marcusenius* (4), *Gnathonemus* (5), *Mormyrus* (4), *Hyperopisus* (one), and *Gymnarchus* (one). The last, *Gymnarchus niloticus*, constitutes a distinct subfamily, having many peculiar characters, in consequence of which Günther treated it as a distinct family, Gymnarchidæ. In Gill's arrangement, published in 1872, the Mormyridæ and Gymnarchidæ constitute the Scyphophori of Cope, and are thought to be nearest related to the Gymnonoti (Gymnotidæ). It is now known, however, that the Gymnotids are really allies of the Characinidæ, and consequently little allied to the Mormyrids. According to Boulenger, the Mormyridæ appear to be nearest to the Albulidæ, but it is recognized that the relationship is not at all close. Thanks to the kindness of Doctor Boulenger and the government of Egypt, I have received specimens of five genera of Mormyridæ proper and scales of *Gymnarchus*. These fishes all have scales of the same general type; cycloid with well-developed circuli and with strong basal radii. The truly remarkable feature is found in the apical radii, which are greatly modified and join irregularly, forming a network, as is well shown in the accompanying drawing by Miss Evelyn V. Moore (figure 1). The apex of the scale is usually broad and blunt, or even subtruncate, while the base is more pointed and narrower.

The following key separates the scales examined:

Scale elongate, much longer than broad..... 1
Scale not thus elongate..... 2

1. Scales near lateral line 7–7.5 mm. long, about 3.5 broad. Yellowish, subopaque, with the circuli extremely fine; reticulation of radii extending down sides, the spaces often diamond-shaped; scales of dorsal region much smaller.....*Gymnarchus niloticus*

Scales near lateral line about 3 mm. long, 1.66 broad, white, translucent, the circuli not so fine; nuclear area more central (River Nile at Assuan) ..... *Mormyrus kannume*

2. Scales oblong, longer than broad..... 3
Scales about as broad as long, obtusely subtriangular, about 2.5 mm. diameter, white; sculpture as shown in figure (Lahûn, Fayoum)... *Petrocephalus bane*
Scales broader than long, very small, breadth 1.25–1.33 mm.; reticulation variable, but reduced (near Luxor)..... *Marcusenius isidori*

3. Scales larger, about 2 mm. long or a little over; about 12 basal radii; apical reticulation well developed (Fashoda).... *Gnathonemus cyprinoides*
Scales smaller, about 1.33 mm. long; about 7 basal radii (near Luxor).. *Hyperopisus bebe*

FIG. 1.—*Petrocephalus bane* (Lacep). Lahûn, Fayoum.

FIG. 2.—Scale of *Mormyrus kannume*. Forsk.

FIG. 3.—*Amia calva*. Plymouth, Indiana. Part of base of scale, showing longitudinal fibers which apparently correspond to the circuli of other fishes.

Thus it is seen that, although there are good specific characters, the scales are in general of the same type, and are, so far as I know, very distinct from those of any other fishes. *Gymnarchus*, according to the scales, goes with the Mormyridæ.

In view of the suggested relationship with the Albulidæ, I was anxious to see scales of that family. Doctor Evermann has very kindly sent me scales of *Albula vulpes*, from Woods Hole, Mass. The scales come from just above the lateral line, under front of dorsal. It may be said at once that they show no resemblance to the Mormyrid scales whatever. They are large (about 15 mm. long and 13–14 broad), quadrate in form, opaque, yellowish, with three (rarely four) nearly parallel basal radii, which hardly extend to the middle of the scale, and which reach the margin at the ends of incisions, the base of the scale being coarsely scalloped with four

(rarely five) lobes. The circuli are extremely fine, and are mainly longitudinal, breaking into a roughened area apically, the whole structure of the circuli being extraordinarily like that of *Amia calva*. This is a matter of interest in connection with the known great antiquity of the Albulidæ.

Another ancient family, placed next to the Albulidæ in the system, is the Elopidæ. Doctor Evermann kindly sends me scales of *Elops saurus* from Jamaica. They are also subquadrate, about 6 mm. diameter, with fine circuli which are complete basally, and here *transverse*, as in ordinary fishes, whereas *Albula* shows in this region *longitudinal* strands consisting of minute segments.[1] The basal structure of *Elops* is evidently more "advanced" than that of *Albula*—much more like that of Teleosts in general; that of *Albula* (except for the radii and the scalloping) differs little from *Amia calva*. *Elops saurus* has a variable number (about 12 to 22) of strong basal radii, which really do radiate from the central nuclear area of the scale, though failing centrally. The apical region of the *Elops* scale is very thin, and shows numerous parallel radii.

Supplementary Note on the Scales of Hiodon.

Since writing the above paper I have received through the kindness of Dr. S. Graenicher scales of *Hiodon tergisus*, from the St. Croix River, Polk County, Wisconsin. In Boulenger's arrangement the Hiodontidæ, which are exclusively North American, follow the Mormyridæ. The scales are large (about 12 mm. long and broad), with the nuclear area between 4 and 5 mm. from the apex. The circuli are excessively fine and numerous, the same all around, and of course transverse in the basal region. Rather numerous apical radii are indicated by obscure broken lines, easily overlooked. The basal radii are very distinct, irregularly placed, a group of seven or eight closely adjacent ones going to each sublateral concavity of the basal margin. The basal margin is not crenulate, and the basolateral angles are distinct.

This is wholly diverse from *Albula*, very distinct from the Mormyridæ, but not far from *Elops*. The silvery skin and minute pigment spots are quite as in *Elops*. *Elops* differs by the modification of the apical circuli, which in the subapical field become coarse, wavy, and transverse, actually at right angles to the lateral ones.

[1] Compare Tims on scales of *Gadus;* Quart. Journ. Micros. Science, Oct., 1905, pl. VI. See also the structure of apical radii in the Serranids *Apsilus* and *Aprion*, as figured by Sauvage in his work on the fishes of Madagascar.

The basal radii of *Elops* are also much more regularly spaced, and the laterobasal angles are rounded.

According to the scales, the four families considered are related thus:

A. Albulidæ.
B. . . . . { *a.* Mormyridæ.
b. . . . . . { 1. Elopidæ.
2. Hiodontidæ.

A remarkable thing about the scales of *Hiodon* is their close resemblance to those of certain old world Cyprinidæ. Comparison may be made, for instance, with *Cyprinus carpio*. The resemblance is such that, if the scales had come to me nameless, I should certainly have guessed them to be Cyprinoid. The Hiodontidæ cannot be directly related to the Cyprinidæ, but I believe that they may stand close to the ancestors of the Characinidæ. I do not know a Characinid scale similar to *Hiodon,* but, of all the South American Characinids, I know scales of only two genera.

SMITHSONIAN MISCELLANEOUS COLLECTIONS

VOLUME 56, NUMBER 4

UPPER YUKON NATIVE CUSTOMS AND FOLK-LORE

BY

FERDINAND SCHMITTER
Captain, Medical Corps, U. S. Army

(PUBLICATION 1933)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
May, 1910

WASHINGTON, D. C.
PRESS OF JUDD & DETWEILER, INC.
1910

UPPER YUKON NATIVE CUSTOMS AND FOLK-LORE

By FERDINAND SCHMITTER,
Captain, Medical Corps, U. S. Army

The Indians at Fort Egbert, Alaska, where I was stationed in 1906, are considerably modified by contact with white men, although many old customs remain as they were before the influences of civilization were felt.

An Eagle Indian village of about 200 inhabitants, 3 miles above the post on the south bank of the Yukon River, proved of particular interest in my research and observations of native customs and folk-lore. These Indians are classified as the Vuntakutchin people of the Athapascan family.

My first inquiry was for a medicine-man, but I was informed that there was none now in the vicinity, all of them having died or left long ago. They were very reserved on this subject and it was two years before I won their confidence, which I at last gained by treating their sick and showing sincere interest in their customs and mythology. One day I was told that a certain Indian named Luke was a good medicine-man. Accordingly, securing the services of the Indian Arthur as an interpreter, we visited Luke, who sheepishly admitted that he had been a medicine-man, but had given it up because the missionaries and police opposed the practice. After a brief conversation Luke became enthusiastic and boasted of his ability, making demonstrations which I will describe later. From medicine the conversation soon ran into folk-lore, with which he was intimately conversant. Arthur was of great service to me here, and later furnished most of the folk-lore which he secured from his father Simon and from the old folks of the village.

Many of my notes in the present paper are left in their more or less crude form, so as to illustrate the native way of thinking; for, since they are intended as records of a people, they should remain as nearly intact as possible. In reading the stories one must not be annoyed by inconsistencies, for they are characteristic of the people. Their "because" clauses, for example, are about as satisfactory as those of a child. It will also be noted that most of their stories begin, "Long time ago, when all animals were men," fol-

lowed with an account of certain animals which were evidently not men. For instance, when the bear goes out to hunt bear his daughter puts on a bear-skin to deceive the hunter. Such oddities will be understood when it is realized that they are traditional or folk-lore.

PSYCHOLOGY OF THE NATIVE

In order to properly appreciate native customs and stories one must be acquainted with the phases of their mental life, in which they are decidedly oriental. They are fond of mystery and mysticism. They have no idea of logic, but readily accept analogy and suggestion as proof of what they wish to believe, and in making inquiries one has to be careful not to ask leading questions, for they will answer in a way most convenient, with utter disregard of actual facts.

Combined with their child-like simplicity is a cunning secretiveness, prompting them to withhold information of any value, as, for instance, if one asks a native how to tan a bear-skin or where to hunt moose, his comprehension is apparently dulled by an assumed oriental ignorance, and in this state he imparts little information.

Shyness is the chief characteristic of the females, resembling the form of insanity known as negativism, but it seems to disappear promptly after marriage. The women hide at the approach of a stranger, and, when spoken to, conceal their faces, seldom answering a question, though they understand English well.

The native believes in a rather concrete existence of dream life, and he sees spirits as if they were real creatures. Only the medicine-man has access to this dream life, and he alone can transfer animals from real to dream life and vice versa. One might assume from the tricks of the medicine-man that he is an impostor, but he is really sincere and believes in himself, although he has the faculty of believing what he must know "isn't so"—the same faculty that we find among hysterics and adherents of various psychic cults.

ANNUAL MOVEMENTS

During the winter season they move about wherever game is plentiful. The men go to a place, cache their packs, and then proceed to hunt. The next day the women come, pitch the camp, and prepare to cook. In the spring they go to the river bank, where they make canoes and nets in preparation for salmon fishing, and during the summer dry and cache large quantities of fish. In the early fall the entire family goes hunting and when a good supply of game is accumulated

they cache it on the spot. In October they return to the river for about two months, when they make snow-shoes, toboggans, and other things for winter use. About the middle of January they have a big time—"all same Christmas"—when they get out all their cached meat and bring it to the river. They stay there till the meat is nearly gone, and again go in search of game until the middle of March, when the weather moderates, at which time they return to the river banks.

The native dog proves a most useful domestic animal during their migratory movements. Each man owns a team of about five dogs, employed in winter for pulling toboggans and sleds over the trails and in the summer for hauling boats up the river banks. For inland travel, when there is no snow, packs are tied over the dogs' backs. Dogs are also used in hunting expeditions, as will be described later. There is no affection between dog and master. The animal is simply a beast of burden, never caressed, but thrashed unmercifully to secure obedience. They are wolfish and snap viciously at any attempt to caress; in fact, they are generally three-fourths to seven-eighths wolf and always gaunt, being given very little food and left to pick their own living. They live outdoors, even in the coldest weather. With the thermometer 60 degrees below zero, I have seen them sleeping comfortably curled up in the snow, protected by their woolly hair, their heads hidden under their bushy tails.

HABITATIONS

These Indians formerly had no permanent dwellings, but lived in tents of caribou skin covering a wicker framework. There was a fire in the center of the tent, and the smoke escaped through a hole in the roof around the tent-pole. When they moved they took the skins with them, but left the frames, which are sometimes seen still standing where Indians have not been for many years. They are spoken of by prospectors as an "Indian sign."

Most of these people now live in roughly built cabins, usually with only one room, that serves for all purposes. The cabin is built of logs, the chinks packed with moss. The roof is of saplings laid side by side and covered with turf. The floor is laid directly on the ground. There is usually but one window, and this cannot be opened. The only ventilation is therefore from door to stove-pipe. A small iron stove, that requires much attention, serves for heating and cooking. A low home-made bunk in the corner or a mass of dirty rags on the floor usually comprises the sleeping quarters.

Sometimes they have a rickety chair or two, but they seem to prefer to sit on the floor. Enamel ware and tin dishes constitute their dining outfit.

DRESS

The original native upper garment was the caribou-pelt "parka," a combination of hood and coat reaching to the knees and without buttons or laces. It was pulled on over the head like a shirt, the hood generally hanging down the back and covering the head only in severe weather. Sometimes sealskin "parkas" were secured in trade from the lower river natives. As far back as any of the present inhabitants can remember, they have worn shirts made of calico which they say traders brought from New York.

With the "parka" they wore a lower garment like the original pantaloons, a combination of trousers and stockings made of moose-skin from which the hair had been scraped.

Moccasins were of moose-skin, with caribou-skin strings to lace and tie them on, and they were of generous size, so that grass or other soft material could be placed in the soles to protect the feet. The moccasins usually reached several inches above the ankle, although low slipper-like moccasins were also worn in camp.

Large moose-skin mittens were made with gauntlet-like wrists, and these are now used and prized by the whites as an article of comfort.

Most of the clothing now worn is that cast off by the white people. Although the skin parka and breeches are still frequently seen, they have been mostly replaced by canvas parkas and other white-man's clothing. The natives, however, do not like shoes. Their moose-skin moccasins are continually wet in damp weather, causing constant headache, and they do not understand that the condition of the feet has anything to do with that of the head.

They wear no head covering in summer, but marten or rabbit skin caps are worn in winter. The old method of hair dressing was to allow the hair to grow long and tie it in a bunch behind with a small bunch over each temple. Swan feathers were chopped fine and applied with grease to the rear bunch daily until it became a large mass. Another custom was to pierce the nasal septum and through it insert rings of small bones from birds. These ornaments were worn especially at dances or other ceremonies, and most of the adult natives still have these holes in their noses.

Porcupine quills, which are used for decorating their clothing, were dyed red by boiling in cranberry juice, or blue by boiling in

huckleberry juice. When any quills were found which were pure white, they were left so. Various colored flowers were also boiled and their coloring matter used in dyeing the quills. Small geometrical figures were made by sewing the flattened-out quills to a backing of skin, and long stripes were made by rolling the quills into spirals about a sixteenth of an inch in diameter and sewing them side by side. The backs of mittens and insteps of the moccasins were decorated with these quills. Flat strings of caribou-skin one-fourth of an inch wide were sometimes wound with porcupine quills. These strings were either sewed to, or tied about the coat wrists and about the breeches below the knees. The coat of a chief was decorated down the front and back, and had a special collar, significant of his office, which consisted of a strip of moose-skin about two inches wide and nearly a yard long with one margin fringed by cutting it into strips. On this was sewed strands, and strings of quills were suspended from the ends. The collar hung around the neck and down the front like a scarf. A special hunting belt was made of caribou-skin decorated with porcupine quills, and from it hung an ornamented moose-skin sheath containing a hunting knife.

Moose-skin is prepared for clothing by the women. After soaking the skin in water to soften it, the hair is scraped off with the end of a sharp bone spatula. As in primitive times, all sewing is still done with bone awls, bones from the fore leg of the caribou or moose being used for coarse work, and for fine work a bone from the fore leg of the lynx or of a bird is used.

The women do bead-work, which they sell to the local stores. These articles and other curios are sold to travelers. Moose-skin mittens are made for local use and are much in demand, as most white people hereabout wear them in winter.

HYGIENIC CONDITIONS

Early Habits.—The Indians say that they had very little sickness before the advent of the whites, and George Matlock, who came to Alaska in 1885, and other old prospectors, confirm this statement. Smallpox and diphtheria struck them in epidemics, but they either died or soon recovered. As military hygiene teaches us, a moving command is a healthy command, and, as the Indians were formerly rovers, camping only for short periods, their wandering necessitated the abandonment of much infected material and localities, thus preserving their health. The survival of the fittest was also a factor

in preserving health, as illustrated by the following incident. A few years ago some government packers were traveling from Fort Egbert to Tanana Crossing, and on their way they passed a camp which the Indians had just deserted, leaving behind a sick old woman and a crying baby, but no attention was paid to them, as it was supposed the Indians would return to get the woman and child. The packers on their return trip a few weeks later found the old woman and child dead, evidently left by the Indians to starve.

Present Habits.—A great change has taken place and conditions could scarcely be worse than they are now. They never wash more than their face and hands, and are consequently exceedingly filthy. Pediculosis and tuberculosis are ever-present indications of their unclean habits. Their cabins are as offensive as their persons. They have no methods of sanitation.

Tuberculosis far outweighs all other ailments. On entering the village one notices everywhere evidence of tuberculosis in the forms of humpbacks, hip disease, scrofula, and consumptive cough. Very few natives can be given a complete physical examination without disclosing some evidence of tuberculosis. Tonsillitis, respiratory disease, digestive troubles, and myalgia are ever present. Diphtheria, according to hearsay, kills off many in occasional epidemics, but there have been no epidemics this year. Heretofore the natives have been in the habit of obtaining medicine free at the hospital, but it has been found expedient to charge a small fee for prescriptions.

These natives are very undesirable patients; they all like to take medicine, but object to physical examinations. They strongly object to surgery and will permit it only under the most urgent circumstances. The relatives of a boy with hip disease were advised to submit him for operation, but to this their only response was, "No cut; make well quick." They will quite readily accept any magic methods, but modern surgery does not appeal to them.

FOOD

The native diet consists chiefly of fish, game, and berries. During July they catch king salmon, which they dry and keep for winter. At all seasons they hunt caribou, moose, bear, and mountain sheep. During the fall, when the caribou run in herds, the natives cache the meat for the cold weather. The other animals are scarcer, and when one is brought in it makes a treat for the village. It is customary, when one native is surfeited with meat, to give what is left

to his neighbor. Ducks are also shot during the fall and spring and make a variety in diet. This meat diet is supplemented by the usual white man's vegetables bought at the local stores. Their nearest approach to vegetable food is the tuber attached to the root of a pennate-leafed weed that grows on the hillside in the shade of spruce trees in the midst of moss, through which the root extends a few inches, the tuber itself growing in the ground beneath the moss. It is six to nine inches long and from one-half to three-fourths of a inch thick, with fiber strands running through it. It has a slightly sweetish but indifferent taste. The natives originally ate it only when they could get no meat, though they say that it is quite palatable when boiled with grease.

Huckleberries and cranberries grow in abundance on the mountain sides and are gathered in large quantities. "Hootchinoo," the native alcoholic drink, is made from huckleberries, by allowing them to ferment. Raspberries, strawberries, salmon-berries, and currants are also found in favorable localities.

The Indians never eat dog meat or wolf meat; they would rather starve. Neither do they eat ravens, hawks, or eagles. They seldom eat wolverene, though they eat lynx and one kind of owl.

These people have lately learned luxury to the extent that they think they are destitute when they have only animal food to eat, whereas, I am told, they never had anything but animal food ten years ago. A contrast to this particular tribe is found when the Mackenzie River natives visit here. These live almost entirely on a meat diet, and are a robust, healthy people.

FISHING AND HUNTING

In July the salmon begin to run up the river, first the king salmon and later the dog salmon. The Indians prefer the latter, for they say the king salmon are too oily. To catch salmon they generally use hand-nets which are let down to the bottom of the river in rather deep places. When the fisherman feels a pull he draws in the net, although sometimes the salmon pulls the Indian into the water. This method, however, is gradually being replaced by fish-wheels. The salmon are brought to the shore where the women, squatting at the water's edge, dress and wash them in the flowing current, split them lengthwise, make transverse cuts about an inch apart through the meat, and put them on pole-racks to dry in the sun until ready for caching.

White-fish is occasionally caught in the nets, and is even preferred

to salmon, which is the staple fish food. Greyling, a kind of trout, is also caught in the mountain streams, and is prized as a delicacy.

The caribou, or Alaskan reindeer, is the staple winter food. During the fall, when a run of caribou is expected, two long rail fences are built converging into a corral. Snares are placed in the fence about fifty yards apart and also thickly interspersed in the corral space where the herd is driven. The Indians line up at the entrance and shoot with their arrows those that try to escape. Some are caught in the fence snares, but most are captured in the corral. The snare consists of a loop of strong braided moose-skin rope, the end tied to a loose log, the loop being held in place by small strings of caribou-skin that break easily. It is set in a natural opening through which it is presumed the animal will try to pass. As the caribou jumps through the loop the strings break, the loop tightens, and, thus caught, he tries to run, dragging the loose log after him, which soon exhausts him. If tied to something firm the rope breaks too readily; hence a loose log is preferred.

Moose are usually stalked and shot with bow and arrow, aim being taken behind the shoulder; but sometimes the dogs get a moose at bay and the Indians attack him with pikes. In the springtime the moose can be caught with snares set in a creek, the dogs chasing him down the creek into a snare. The Indians say that a moose once shot with an arrow never escapes, as they sometimes do after being shot with a gun, for, though they may run for some time, they will finally succumb and be caught.

A pike or spear is nearly always used in hunting bears. The hunter attracts the bear by making a raven-like noise, causing the bear, as the Indians say, to think the raven has discovered a dead moose. They also further explain that the big bears only would come, as the little bears would not know what the croaking meant. As the bear approaches the Indian holds the spear in position, facing the bear as it draws nearer to him, and as the bear springs the Indian sticks the spear into its throat at the top of the breast-bone, at the same time shoving the handle of the pole into the ground, thus causing the bear to spear himself with his own weight. Sometimes three men hunt in this manner, two of them attacking the bear on either side as it rushes forward. The meat of the young bear killed in the fall, when they feed on huckleberries, is considered a great luxury.

Grouse, ptarmigan, ducks, rabbits, owls, hawks, and other small game are killed with a dull, round-pointed arrow, sharp-pointed arrows being used only for big game.

The eagle cannot be shot with an arrow, but is snared. For this purpose a small fence having a snare at one side is built on a mountain peak and baited with a caribou lung. The Indians say that the eagle is very wary and will not go in at the top of the snare, but usually alights near it and inspects it carefully before entering, which he eventually does and is caught.

COOKING

Baskets for cooking are made of spruce roots, and, though they leak when new, they soon shrink and the crevices become filled with grease. Each Indian woman keeps near at hand during the winter a stone which is used in cooking, as follows: First it is heated in the fire, and when it is red hot the ashes are brushed off and the stone dropped into a basket of water, making it boil in about a minute. These stones are hard to procure in the winter and are guarded most carefully. Sometimes birch-bark baskets are used, but, since they break easily, are of little service except for cooking and drinking utensils on a hunting trip. The spruce basket is preferred, since it is collapsible and can be rolled into a small package.

Meat is roasted by suspending it on a string from a cross-bar on two supports near the fire, where it is continually twirled until roasted. Salmon is cooked a little differently. Usually it is hung at rest with the flat inner surface toward the fire. Rabbits, ptarmigan, moose-foot, and other small things are roasted in a pit-oven, made by building a fire on the ground in the sand. After the fire has burned for some time it is brushed aside and a hole dug beneath it in the sand. The meat is placed in the pit, covered with hot sand or dirt, and over this the fire is rebuilt and kept burning until the roasting is finished. Ducks, geese, and swans are boiled in a large basket of water by means of the hot stone.

NATIVE DEVICES AND IMPLEMENTS

One method of starting a fire was by the flint and iron-pyrites method, in which a piece of flint fastened to a stick about three inches long was struck against a piece of pyrite to produce a spark. Punk to catch the spark was usually secured from a fungus growing on birch trees. The Indian word in the Porcupine language for flint was "vetrih," and pyrites "tshi tlya." Another method of fire-making was with the whirling stick. The stick was braced between the body and a piece of punk. A string was wound round the stick,

so that pulling would revolve the stick rapidly in either direction, starting a friction fire on the punk.

They still have hammers made from a rounded stone fastened to the end of a stick with a string of caribou-skin. These are used to break up bones for cooking, and to make arrow-heads. My interpreter has seen stone hammers in use, and he also says that stone axes for chopping down trees were used some time ago, although he never saw one. Hunting knives are made of bone ground flat and sharp on both edges, and they occasionally have copper knives of the same pattern, which were secured in trade from the White River Indians. One of their most useful weapons, the spear, was made by binding a hunting knife of caribou-horn to the end of a pole about 6 feet long.

Birchwood is used for making bows, arrow-shafts, frames for fish-nets, snow-shoes, toboggans, and canoes, and their woodwork is nearly always painted with red ochre, which is secured from the banks of a creek near the village of Nation, about thirty miles down the river from Eagle. They say that this creek is red from the ochre, which can be gathered in handfuls from the mud in the swampy places along the banks. In former times this pigment represented an important article of commerce, and was carried to a great distance and traded with other tribes. They used it also for painting their faces in the dances.

"Babiche" is a tough string made of walrus hide, secured in trade from the lower river Indians and used for making snow-shoes and fish-nets.

Arrow-heads are about five inches long and made of caribou-horn or bone, and bound into the split shafts with fine sinews.

The natives still build a style of canoe characteristic of the upper Yukon. It is of birch bark, fastened to a frame by lacing with the slender roots of trees. The bark is fitted over the frame, and then about a dozen squaws hold a sort of sewing-bee, as they sit along the sides of the canoe and lace the bark through holes punctured along the edges by a sharp bone awl. The cracks are filled with pitch by the supervisor to make the canoe water-tight. This is a product entirely free from the influence of civilization. White men do not use them, because they tip too easily.

AGRICULTURE

The natives in this locality pay no attention to agriculture. There is excellent opportunity for it, but they have never been taught. About their village there is much more rich garden land than they can use. The white people grow an abundance of potatoes, carrots, turnips, cabbage, cauliflower, onions, and other vegetables. One man raises wheat, barley, and oats. In a single season a garden 100 feet square will yield five hundred dollars' worth of vegetables (according to Alaskan prices).

There are always a number of natives loafing around the village, many of whom are unable to hunt on account of age or consumption. To give them work in a garden would be an excellent hygienic measure.

GOVERNMENT

Under their primitive form of government the chief (ha-kkih) had despotic authority. He detailed hunting parties and dictated their duties, and when game was brought into camp he assumed charge of it, apportioning it out to whom he pleased. The chief of the Moosehide Indians near Dawson shows much of the pristine dignity and authority of his rank, and whenever he buys anything in Dawson he does not carry it home, but sends an Indian after it. He shows his genteel extraction by always wearing a pair of fancy decorated gauntlets when he goes on a several days' visit to Eagle during warm weather. During the absence of a chief, or when he is incapacitated, a patriarchal form of government exists, and all important measures are decided by the old men after holding the "big talk." Public opinion is very strong and each individual has great respect for the opinion of the community concerning his personal actions.

For several years the chief of the Eagle Indians did not attend to public affairs on account of age and feebleness; hence the functions were carried on by the old men. At one time a chief from farther down the river came here and assumed to be chief, but he was never generally recognized as such and ended his career when he fled from the village and the police.

Their life is somewhat communal, each family living by itself, but in a small tribe most of the families are inter-related. They occasionally marry into other tribes and sometimes children are adopted into a family. Joseph, the chief at Ketchumstock, has two boys which, it is said, were taken from Tanana when they were

infants, and, strange to say, such kidnapping appears not to be considered a serious offence.

POLITICAL AND DOMESTIC ECONOMY

The native idea of money value is very unstable. In this respect they are the victims of unfortunate circumstances. I am told that in 1898, during the gold rush, many natives were hired as pilots and guides at $10.00 per day. This gave them an exaggerated notion of the value of their labor, to which they cling tenaciously. The smallest piece of money current in any of the Alaskan stores is twenty-five cents, so the native regards a twenty-five-cent piece about the same as a laborer in the States regards a cent. An incident will illustrate: I saw a white traveler take a picture of a native family and give the paterfamilias twenty-five cents as a tip, but he superciliously tossed it to his baby, considering it too trivial a reward for himself.

The wages of a white man in this country average five dollars a day. This compensates him for labor and things incidental to working away from home. The native has a keen appreciation of his own value and will not work for any less than the white.

The lowest price usually assigned by a native to any piece of work is five dollars. I have seen one refuse to tan a small bear-hide (worth about $4.00) for less than five dollars, although in a few days his wife was seeking destitute rations.

While these people will not come down from a set price, their failure to appreciate comparative values allows them to be cheated. The following incident will illustrate: A native had a pail of berries for which he wanted two dollars; a store-keeper offered him one dollar, which he refused. Then the store-keeper threw down three bars of soap, worth thirty cents, and offered them in trade, which offer was promptly accepted.

The natives are very improvident. They will loaf continually in the summer, gathering no firewood for winter. In cold weather they will huddle together in a poorly heated cabin, and I have known them to tear down cabins for firewood and rebuild when summer comes. When they have much dry salmon in the summer they sell it to the stores, but when winter comes and they run short they buy it back at a higher price.

MARRIAGE

An interesting old custom was that of the arrangement of marriages during the infancy of the children. The question was settled by the parents, who met in consultation and made all the arrangements for the prospective marriage, choosing for the girl a boy usually about three years older. Between the ages of 10 and 15 the boy left home to live with the girl's parents, although they were not married until the boy was able to hunt and work. The boy became a part of his wife's family and never returned to his own.

Marriage usually took place between the ages of 16 and 20, but sometimes as late as 25 years of age. Although the agreement had been made by the parents of the intended bride and groom, yet their own desires were considered before the actual marriage took place, and they were not forced to marry unless they felt they were suited for each other.

On the death of a wife or husband it was not customary for the survivor to remarry for several years, since the relatives of the deceased might think the survivor was glad of the other's death.

CEREMONIALS

These Indians are quite strong in tradition, and no household event is passed over without ceremonious observances that usually take the form of "banquets," given by the person immediately interested. Thus, at the birth of a child the father celebrates the event by giving a dinner to the entire tribe. A similar banquet is given when the oldest boy kills his first bit of game, thereby attaining his majority and proving himself a hunter. It is incident to the custom on this occasion for the youth to present a bird to the head man of the tribe, while his father also makes the chief a present in token of his esteem and pleasure at his son's accomplishment.

Corresponding to the feast in honor of the boy's maturity, a similar celebration is held when a girl arrives at the age of puberty. Everybody in the community is informed, and the girl's father gives a dinner in honor of the event. The girl then goes about a mile from home, where she lives in isolation for a year under the care of a relative of her fiancé. She does not eat fresh meat during this year, and if she breaks the rule it is supposed to make the game few in number and hard to get during the ensuing year. As a punishment, in case she violates this tradition, she is compelled to stay away for another year and wear a peculiarly fashioned cap in the

form of a cape which extends to her knees. This is to prevent her from seeing any men, though she may talk to them. She may raise her cap only to do sewing or other work in her tent. This custom is still in vogue, but the length of exile is usually cut down to a few months. A neighboring tribe has a custom of not allowing the girls to drink from anything but a special ceremonial drinking cup made of woven roots. This is not allowed to touch her lips; she drinks by making a gutter of the palm of her hand, through which she pours the water into her mouth.

FUNERAL CEREMONY

When a chief, "Ha-kkih," died, men were hired to burn his body, and what was left of bones and ashes was placed in a wooden receptacle hewn from a tree trunk and hung about ten feet high in a tree. The men who burned the body ate no fresh meat for a year, because, according to the law, if those who worked for a dead man should eat fresh meat within a year they would die. They could eat dried meat, but if there was none dried they must wait until some was made.

It is an old tradition that when persons die they go into a woman and are born again as a baby. The man is born again as a male and the woman as a female. They have no notion of transmigration into animals, believing that when an animal dies it is not born again as a man is.

Last winter the Eagle chief died. He had hoarded up much wealth of skins, blankets, traps, rifles, and other property, and, since it is not customary among the Eagle Indians for relatives to inherit the property of the deceased, his kinfolk received nothing of his belongings. By common consent Old Peter took charge of the effects. It was then announced that there would be a "pot-latch" in the spring, when the goods of the deceased man would be given away. Invitations were sent east to the Moosehide Indians up the river, west to the Charlie Creek Indians down the river, and south over the hills to the Ketchumstock Indians. The Porcupine Indians to the north were not invited, because they were not related to the tribe. All the goods were kept intact in the caches until the arrival of the guests. Then Isaac, the Moosehide chief, took full charge of the ceremonies, which lasted several days, during which there was much feasting and dancing. At the dinners, the men first gorged themselves, allowing the women to come in after they had finished and take what was left. Between the ceremonies they assembled

in groups about the village and gossiped or sung to tunes resembling those of Japanese operas. Time was kept by one of the Indians beating upon a caribou-skin drum, while everybody swayed to the time, alternately bending the right and left knee. For the final ceremony a fence about seven feet high was built about an enclosure thirty by sixty feet. The "pot-latch" proper was held in this enclosure during one afternoon, and the people sat about near the fence facing the goods of the deceased, which were displayed at one end by Chief Isaac, who stood in their midst and presided. The first hour of the ceremony was very much like a church meeting, all talking in their native language. The chief then opened with a speech, and when he sat down others rose and spoke as the spirit seemed to move them, apparently eulogizing the great chief. At times the speaker became much wrought up, his gestures showing that he was illustrating a fight with an animal. After the speech-making the goods were distributed one article at a time. The chief would pick up a blanket, walk down the center of the assembly, and with a few remarks toss it to some one, the recipient smilingly responding with brief remarks. Articles were only given to the visitors; the Eagle Indians received nothing.

After watching the ceremony several hours, I was about to leave when the chief called me and handed me a pair of moose-skin moccasins, saying, "This is because you were good to my people."

Next day the food became scarce, so the visitors began to depart for their homes, their toboggans laden with goods from the deceased chief's cache.

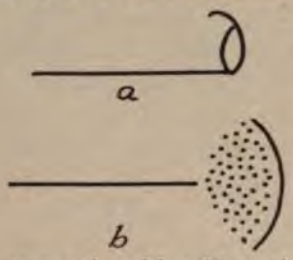
NAMES

A few of the most important Indian names have been given in the previous paragraphs under other subjects. The Eagle Indians themselves are called "kkwi dyik" in their own tongue. In the Porcupine language they are called "vun tte kwi chin," which means "the people of the Willow Creek," since they came from what is now known as Charlie Creek, where willows abound and from which the creek was named by the natives.

Individuals were given names from incidents of their infancy. Old Simon's name, "Da Hoch," meaning white blood, was chosen from the fact that he had a suppuration in one of his eyes since infancy. The Indians are generally known to the white people by Biblical names which missionaries gave to them.

SIGNS AND SYMBOLS

The Indians do not write, but make signs of one sort or another, a few of which follow. The sign *a* drawn in the snow means a moose in the direction of the end of the line to which the head is attached. The sign *b* in the snow means caribou on the mountain in the direction of the straight line.



Along a trail, where it divides, if one sees a leaning pole with grass tied to the end, it means no "grub" in that direction, or a pole with willow tied to the end means plenty of "grub."

GAMES

The Indians had an outdoor game similar to volley-ball in which several took part. A ball the size of a baseball, made of caribou-skin stuffed with hair, with a marten tail attached, was used in this game. A party of about ten Indians would take up their position on each side of a line, batting the ball with bare hands from one side over the line to the other, and every time the ball touched the ground it counted against the side on which it fell.

The boys had a game that not only furnished sport, but gave them practice in throwing the spear as well. One person would roll a hoop made of willow before a number of Indian boys standing in a row, each with a long spear-like stick, which he threw at the hoop as it rolled past him, and when one went through the hoop it counted as a caribou killed.

For an indoor game they had one which is not uncommon nowadays. In this game the men sit on the ground with their legs arched in front of them and the women sit tailor fashion, each person having a cloth similar to a handkerchief. Any small article is started down the row; the men pass it under the knees and the women pass it behind their backs, the object being to conceal the article in the cloth or stealthily pass it on without being caught. It was the duty of one to catch a person with the article in his possession. Men and women sit separate in rows opposite each other and watch the other sex play the game.

The nearest approach to gambling among the natives is an old game, the rules of which are as follows: Two rows of men sit opposite one another, each man holding in his hand a bone marked with a

notch. The bones are secretly passed from right to left and vice versa. Some one on one side would call out which of the opponents' hands contained the bone, and the calling side would get as many sticks, from a pile of about sixty, as the number of opponents' hands guessed correctly. Each side called the other alternately. Sometimes they would hold another unmarked bone in the opposite hand so as to confuse the guesser. The side which lost or got the fewer sticks had to give the other something as a forfeit.

They wrestle "catch-as-catch-can," but they usually try for a hold in the following manner: Putting the right arm around the opponent's waist and grasping the breeches at the thigh with the left hand. It is only necessary to throw a man, for as soon as he falls he is beaten. As a mark of friendship on separating, after this sport, the Indians exchange coats or other articles of clothing regardless of their value.

THE MEDICINE-MAN

The word "medicine" should be understood as synonymous with "magic." The medicine-man does not administer potions, but cures by other methods; thus, "make medicine" is synonymous with perform magic; hence, his aid is sought for more purposes than healing the sick, and he can perform to defeat the enemy, to overcome famine, or to make a prospective hunting trip successful. When a man is sick he calls in this Indian doctor, who sings to drive away the disease. Each medicine-man has his own way of singing, though the general form is a chant like those used in dances, in which words are sometimes used, but generally meaningless syllables. The medicine-man goes to sleep and dreams songs, and what he hears in the dream he repeats as an incantation over the sick one.

When Luke, one of these medicine-men, now perhaps forty years old, was a little boy, about 500 Indians encamped in skin houses about a mile up Mission Creek were taken with smallpox and most of them died. The remnant of the band migrated to Forty Mile, where they were attacked in 1897 by an epidemic of coughing and bleeding from the lungs, and many died in from four to six days. The Indians think that each of these epidemics was due to a bad medicine-man from elsewhere sending an evil spirit amongst them. The evil spirit was supposed to enter the man's body in the form of an animal and, by moving about in him, produced sickness.

It seems the medicine-man is still able to do this by taking a weasel skin and causing it to disappear in various ways. Sometimes he

holds it in the fire, whence it disappears without being destroyed, going into its victim; or the weasel skin may be caused to disappear by wrapping it in a cover or holding it between the palms and blowing a puff of breath on it. A medicine-man tried to demonstrate this to me, but the skin did not disappear, though I was assured that it would disappear in actual practice.

The weasel was called a "fetich," and this name applies to other animal skins used in the same manner, such as the marten and wolf, or, in fact, whatever animal the medicine-man sees in his dreams and wishes to employ in his practice. The skull and claws are sometimes removed from the skins, but generally are left on. Formerly they were ornamented about the neck and mouth with porcupine quills, but more recently with glass beads. Although a skin is still most popular, there are many other fetiches in use. A beaver's tooth, wound with beads and suspended on a string, is a useful fetich, and is made to disappear and reappear at the convenience of the medicine-man. Small bones are decorated and used in the same manner. A great many medicine-men dig a certain kind of root from the ground which they carry about in their pockets. It appears to be alive and at times grows larger or smaller. Some medicine-men employ the sun, moon, or stars in their songs instead of an animal, while others call upon the trees, birds, brush, or any convenient object.

The good medicine-man works in the opposite way from a bad one; he cures a sick man by drawing the weasel skin out of the ailing part. I was shown how it was extracted from the ribs, neck, or head. With the skin concealed up his sleeve, or hidden in his clenched hand, the medicine-man reached to the affected part, whence he jerked it forth in the twinkling of an eye. Sometimes in sickness, when all the friends are assembled to assist the medicine-man in singing, he will brush the affected part with his hand as he sings until, with a puff of breath, he blows the disease away. At other times he will firmly grasp at something invisible and appear to pull it out and throw it into the air, driving it away with a puff of breath. The medicine-man, after extracting the evil spirit, returns to the animal its own spirit and sends the evil spirit back to its original sender, whom it kills, because he sent it first.

Whenever a sick man dies the bad medicine-man takes back the evil spirit, and these spirits, which he sees only in the form of animals in his dreams or when he sings, are kept for future use. It is believed that a stronger medicine-man can kill a weaker one's ani-

mal, thus stripping the latter of his power, who thus becomes like any one else and liable to destruction by the stronger one.

If a man wants to become skillful in magic healing he goes to sleep in the same blanket with a medicine-man. When they are asleep and dreaming he is taught the medicine by his instructor. The medicine-man, however, is disinclined to teach others, because he is apt to lose his power and since a stronger one could kill him. A bad medicine-man likes to kill, but a good medicine-man always wants to cure, and it is said the good are apt to live longer.

Their treatment of wounds is most interesting. If a wound bleeds profusely, the medicine-man gets a piece of king salmon skin the size of the palm and cleans it of scales. He takes this between his palms and has another Indian hold his hands together for security; then, as the medicine-man blows, the salmon skin disappears, going into the wound, where it forms a membrane and stops the bleeding. This is extracted again when the wound is healed. This method is also employed when there is a pain but no bleeding.

An odd test used in case of sickness is to put a frog on top of the man's head; if the frog soon jumps away the man dies soon, but if the frog remains on his head for any length of time the man will live a long time.

Last winter one of the Indians had severe tuberculosis, bronchitis, and pleurisy, for which I treated him, unaware that he was a medicine-man, and during the spring he recovered. He has since confided to me that his illness was caused by a bad medicine-man from "Tanana," who sent the quill of a large eagle feather that entered into him and caused his sickness. He insisted that he extracted this quill in the presence of several witnesses, thus defeating with his magic the machinations of his enemy and curing himself. One of the witnesses assures me that this actually happened.

Disease is not always the result of the medicine-man's evil spirit, but sometimes comes of itself, so the Indians have certain actual medical remedies. If they have a cough they chew grass roots or spruce bark to stop the illness, and sometimes the old women boil bark, roots, and brush to make tea, which is drunk for all forms of illness. Originally many kinds of bark were infused in the same mixture, making a sort of general remedy, for it seems probable that the specific use of these herbs was not acquired until later from the whites; at least the medicine-man never used them or any other drug, his practice being limited to psychotherapy.

In war times the medicine-man performs his magic against the

enemy. In experiments of this nature a medicine-man uses for a fetich two pebbles, a few inches in diameter, with natural holes in them, tied to the ends of a string about a foot long, made of caribou-skin wound with porcupine quills. In demonstrating the use of the pebbles, the magician pointed to an imaginary enemy in the distance and, assuming an attitude of forward charge, his countenance showing fierceness and his eyes the glassy, vacant stare of the mystic, he suspended the pebbles by the middle of the string, swung them forward three times, blew on them a puff of breath, and with full strength threw them toward the enemy. Immediately relaxing, with a smile of satisfaction, he said, "They run."

INFLUENCE OF CIVILIZATION

There is an Episcopal mission at the village which most of the natives attend faithfully. It is their principal form of diversion from lying about in their squalid cabins. Strange as it may seem, the most stupid ones and those who cannot speak English make the better church-goers, while those who are more intelligent and can talk English associate with and come under the influence of the saloon loafers. Accordingly, the few crimes I have known to be committed by the natives were by the most intelligent members of the community. Even the bad Indians go to church, though they are hypocritical. I have seen a native take communion, get medicine from the hospital as a destitute, and a few days later offer a white man five dollars to get him some whiskey.

These people have learned to be charity-seekers and the church, it seems to me, maintains a weak influence over them by doling out charity. This is undesirable, for charity is not necessary, since there is opportunity for them to be self-supporting provided they are properly taught occupations and to despise instead of to seek assistance.

In view of these conditions, a Government official should be appointed or detailed to teach the natives agriculture, to act as a health officer and to compel them to live in a sanitary manner, to supervise the care of the sick, to establish a commissary where they may buy at moderate prices, to act as police, and to make further recommendations for their benefit.

FOLK-LORE

The following stories were collected from various individuals, and are presented, as nearly as possible, in the style of the narrator:

CREATION OF THE WORLD

Long time ago the water flowed all over the world. There was one family and they made a big raft. They got all kinds of animals on the raft. There was no land, but all water, and they wanted to make a world. The man of the family tied a rope around a beaver and sent him down to find the bottom, but the beaver didn't reach bottom; he got only half way and drowned. The man then tied a string around a muskrat and sent him down; he reached bottom and got a little mud on his hands, but he drowned. The man took the mud out of the muskrat's hands into his palm and let it dry, then crumbled it to dust. This he blew out all over the waters and it made the world. (All tribes about here are said to have the same story.)

ORIGIN OF THE WIND

A long time ago, when all animals were men, there was no wind. There was a bear that used to go about with a bag on his back. Many people were curious to know what was in the bag and they often asked the bear, but he would not tell them. One day another man caught the bear asleep with the bag on his back. The man's curiosity to know what was in the bag was so great that he cut it open. The bag contained the wind, which then escaped and has never since been confined.

THE OLD MAN AND OLD WOMAN

In the Yukon River between Eagle and Fortymile there are two large rocks which evidently were one before a geological cataclysm separated them. The natives call the one on the north side the "Old Man," and the one to the south the "Old Woman." These were the primogenitors of the Indians in this region. The story follows: These two old folks were once together in the middle of the river, but the old woman pushed the old man to the other side because he left her there. So he went north and she went south, but the children grew up around there. At that time this region was full of all kinds of animals, and they could talk like men. The old man killed off all the bad animals and saved one good one of each kind, which started the families. They have since been unable to talk.

The moose was the head game of the world, because the old man killed the bad moose first. The big swan was once the head of all birds and animals because it was stronger. All animals came together and had wrestling matches. The little teal duck was the strongest animal in the world. First the swan beat the moose, but the teal duck beat the swan after the swan had conquered all others.

ADVENTURES OF THE OLD MAN

The "Old Man" (rock) in the Yukon went down the river where the bear, when bears were men, was fishing. He put his canoe on this side of the river where no one could see it from a point above where the bear was. Then he made a circuit on foot around the bear and reached the river lower down.

The old man then swam up the river, like a king salmon, to the bear's house, where the bear was spearing salmon. The bear tried to spear him for a salmon, but he grabbed the spear point, broke it off, and swam to his canoe and hid the spear point under the bow. Having disarmed the bear he now knew that he was safe. So he got in his canoe and went down to the bear's house to call. He concealed the fact that he had broken the bear's spear, but the bear believed that he did it, nevertheless. The bear wanted the old man to marry his daughter. The bear pointed to a mountain about a mile away, where there was no timber, and said that it was a good hunting place for bear, since a bear came up there every day. The old man went to the woods to get material to make some arrows. The bear had everything fixed dangerous about there, so that when a man touched a tree stump it would fall on him. The old man was cautious and would touch a stump and dodge when it fell. Then he secured the wood for arrows from the fallen stump. Now he wanted some feathers and the bear took him to a place said to be good for getting them. Here were big eagles that would kill men. The old man went to an eagle's nest in a big tree, where there were two young ones. He asked them which one could talk most. One said that he could talk most, and would tell the father and mother eagle about everything, so the old man killed him so that he couldn't tell. He asked the other young eagle how he knew when his mother was coming, and was told that she always followed a gust of snow. He asked when the father eagle came, and was told that he always followed a gust of hail. Then the old man hid under the nest with his spear. Then came the snow and the mother eagle appeared, carrying the upper half of a man. She asked the young one, "Where is your brother?" and he said, "It was too warm here and he went down where it was cool." She said, "I smell something here; what's the matter?" The young eagle said, "You smell that half a man;" but the mother eagle said, "I smell something different." Then the old man under the nest speared the mother eagle, piercing her from belly to crop. Then came the hail, and the father eagle followed and asked the same questions as the mother. He said to the young one, "Where is your mother?" and the young one answered, "She went down to look for brother." The father eagle brought with him the lower half of the man. Then he said, "I smell something," and the young one replied the same as to his mother. The old man was watching from under the nest, and he speared the father eagle too. This father eagle would kill any man he saw. The old man saved the young one. He got enough feathers to make his arrows. When he came back the bear said, "You're all right," which he always said. The old man wanted some pitch to stick the feathers to the arrows. The bear, as usual, led him to a dangerous place, where he told the old man there was plenty of pitch. Here the old man found a lake of pitch boiling like water. The old man wouldn't go near it, but took a long willow switch and dipped it into the lake. With this switch he threw the pitch all over the spruce trees about him. The spruce trees theretofore had never yielded pitch, but have done so all over the world ever since. Then the old man gathered enough pitch from a spruce tree and returned. Now he wanted sinews to bind the feathers and heads to the sticks of his arrows.

The bear led him to a moose lick where there was a bad moose. The moose didn't have much flesh, but was mostly bone and skin. His hide had such stiff hairs that it was hard for an arrow to penetrate. This moose would kill

every man he saw. There was lots of high grass about there and the old man crept up to the moose on hands and knees through the grass, keeping out of sight of the moose. When the old man got near the moose he stopped and wished for a mouse to come along. He told the mouse to go to the moose and chew the stiff hair off behind the left shoulder. The mouse went to the moose and asked to chew the hair off behind the left shoulder, to use for his nest to keep the young warm. The moose refused, but told him he could chew the hair from his hind quarter. The mouse insisted that he wanted the hair from behind the left shoulder because it was soft and warm. So the moose allowed him to take it. As soon as the hair was oft, the old man shot the moose through this spot into the heart, killing him. Then the old man got his sinew from the spinal ligaments of the moose. Then he returned to the bear camp and finished making the arrows. The old man made the arrows with birch-bark heads because the bear said the birch bark was the best. The old man knew that this was false, but he did it to please the bear. The bear said that upon the mountain where there is no timber a bear came every evening, and that the old man could get it. The bear was accustomed to kill men by this ruse. He set his daughter up there dressed in a bear skin, and when a man came near she would hold him till her father bear killed him. The old man concealed bone arrow-heads in the back lock of his hair before starting. The old man and the bear started out to hunt bear. The bear said, "Walk slow" but the old man ran away. As soon as the old man approached the hill he saw the other bear and shot twice with his birch-bark pointed arrows, but they didn't penetrate. The bear when hit, instead of running away, as ordinarly, came toward the old man, who pulled the bone arrow-head out of his hair and shot the bear with it. He now saw it was the bear's daughter, for she hollered, "Father, that man hurt me." The bear said to her, "Catch hold of him," and as she tried to catch him she died. Then the old man ran away and the bear chased him all day. Then the old man ran into Ford's Lake. (Calico Bluff, six miles below Fort Egbert, on the Yukon, is called "Long Point" Clavath, pronounced "Klay-vay," and Ford's Lake, near by, is called Clavathmon, meaning Long Point Lake.)

The bear couldn't catch the old man, so he told the frog to drink all the water in the lake, and the frog drank it all. As soon as the water was gone the old man burrowed into the mud. The bear went all around digging in the mud to find the old man. As soon as he got near the old man, the old man wished for a snipe to come along and it came. He asked the snipe to go and hit the frog twice in the belly. The frog asked the snipe, "Did some one ask you to come?" The snipe said, "No, I am hunting for something for my children to eat." As soon as the snipe got near the frog he hit it twice in the belly and flew away. Then the water all ran back into the lake. The bear now was angry, and made a fish trap, which he put in the creek, from Ford's Lake to the Yukon River, to catch the old man. The old man knew this and made a mud man, which he pushed ahead of him, swimming down the creek. The mud man went into the trap, the bear pulled it up, and the old man swam down to the Yukon and down to the bear's house below Calico Bluff, where he got his canoe and went down the Yukon, and the bear never saw him any more.

THE MIRACULOUS LITTLE MAN

Long time ago, before the "Old Man" and "Old Woman," lots of Indians were together and they fought until all were killed except an old woman and her daughter. This old woman cried every day because there was no man to help her do her work or get her wood. Every day when she had to get her wood from the brush she cried, and each day she had to go a little farther for the wood. One day she heard a sound like a baby crying in the woods. At first she did not go to see what it was, but told her daughter, for she knew there were no people there. Her daughter said, "Next time you hear it; go to it, and if you find a baby bring it." She went for wood again and heard it, and going to it she found a baby boy at the foot of a spruce tree. The boy was not born, but found by the old woman in the brush. When she brought it mother and daughter rejoiced, for bye and bye they would have a man. As soon as they got him home he became strong and could work. As a joke the old woman told him to take their dog and go out hunting, thinking that he didn't know how. She told him to tie a rope around the dog's neck. He tied it on the dog, then went out hunting, and on the way he pulled so hard that he choked the dog and dragged it back with him.

The old woman still had friends in another place. So she and her daughter and the little man went amongst these Indians again. The boy was small and didn't grow. When he went hunting he would put on an eagle-skin like a coat and fly. He was a pretty good hunter. People asked him, "How do you cut moose with a knife? You are too small." He said that when he kills a moose he is like a big man, but is small when he comes home again. He does all miracle work. He does not bring his eagle-skin home again, but leaves it two miles away on a tree. The daughter found the eagle-skin and took one tail feather to stick in her hair. The boy found it out and was angry, so he said to his sister, "I wish all your friends would be killed again." Then she said, "What are you going to do with your mother?" (the old woman), and he said, "I will put her in the corner of the birch-bark basket." In a little while war came and all were killed except the old woman and the daughter and the little man. Then the little man made lots of very small arrows and made a few from a bear's ribs. He worked all the winter making these arrows, because he was going to fight the people all by himself. These people who killed his friends lived by a big lake. The old woman was with the little man, but the daughter had been captured by these people. He got lots of bags for arrows, and, being small, he walked under the snow and hid a bag of arrows about every 50 yards apart, so that when he shot away his arrows in fighting them he could run back to get some more. When he came near, the people thought that he was a raven because he was such a small black thing. His sister said, "You people didn't kill the little man with the old woman." There was one man who wasn't in the fight, so he was selected to kill the little man. The man took a small stick to kill the little man, thinking it would be easy, but the little man threw a small object at him, striking him in the chest and killing him. Then all the people, thousands in number, ran after him without their arrows, because he was too small to shoot. He ran back the same trail on which he came. He would come out of his hole and shoot some; they would rush after him, and back he would go and come up elsewhere and shoot again. Every time he shot he killed. He killed all those people in a day. He brought his sister back to the old woman at home.

After the fight he said he would make a big pot-latch (a celebration with feasting and giving of presents), because he had wounded and killed lots of people. Then he went hunting every day, and killed all kinds of game and saved the hide and meat. The mother and daughter tanned all the skins, dried the game and cached it. The little man said he was going to give the skins as presents to other people. The old woman said, "All the people are killed, so who can you give them to?" and he said, "Bye and bye lots of people will come." This was on a big island just this side of the Old Woman rock. When he collected his meat and fur he began to sing every day that he wished that lots of people would come from up and down the river to the pot-latch on the island, and they came without being told. They all moved about together and sung as usual at a pot-latch. When they did it the island cracked in two parts, because too many people were on it. The people feasted every day. After the feasting he gave away all kinds of skins and furs. He made the big time because he killed lots of people and was sorry for it. He killed the people because they killed his friends first.

THE BOY IN THE MOON.

See the mark in the middle of the moon like a man? That was a little Indian boy when nobody had anything to eat. During the famine this boy dreamed that they were going to kill lots of caribou.

The boy said that when they killed all the caribou he wanted the leader caribou. The boy's uncle gave him the wrong caribou, because the uncle did not believe the boy dreamed it. Then the boy cried for two nights beacuse he didn't get the right kind of caribou. The boy told his father, who brought home the hind quarter of caribou, to never cut the flesh off it to the bone, but to cut off what he needed, wrap it in a skin, and put it under his head to sleep on. The father did this and when he awoke he found a whole hind quarter, and thus forever he could eat caribou from this leg and always have it whole. Next night the boy, who always slept between his father and mother, was gone and nobody could find him. The boy wore marten-skin pants. In the morning the left leg of the pants was found on the tent-pole where the hole is in the roof for the fire. Hence they concluded that he went up through the hole and the left pants' leg was torn off going through. He went up to the moon and was seen there the next night, and it was proved, for he had a larger right leg than left, because the right leg has pants on. From his right hand hangs a little round bag with the wrong caribou meat in it. That night a big storm came and snowed all over where the caribou was cached. Then all the killed caribou came to life and went away, and the Indians couldn't find their meat. Then they all starved to death except the boy's father and mother. During the fall and winter with clear sky, one who has been properly instructed can readily make out the outline of this boy in the moon.

THE CAMP ROBBER

The camp robber is a slate-colored Alaskan jay, well known for its habit of stealing food from camps.

When all animals were men the camp robber was a medicine-man. One time the people had nothing to eat, and they asked the medicine-man to get them some food. For six nights a different man each night dreamed to find a way to get something to eat. The camp robber was the last and sixth man.

He dreamed and called all the people together to bring their snares with them. He made a pack of the snares and put them on his back. The people made the snow in a big heap. Around this he went, chanting and saying, "Bye and bye meat will come." Then he reached into the snow heap and pulled a caribou's head out by the horns. He did not kill it, for it was not a real caribou; only a spirit. So he painted the horns and tail red, with red ochre, and let it back into the snow heap. Next day they got lots of caribou, and the one with red horns and tail was amongst them. That is why an Indian never kills a camp robber when he steals grub, but lets him go because he helped them in the days when he was a medicine-man.

THE RAVEN

The raven lies more than any other game. Long time ago all the animals were good except the raven. He was an habitual liar and robbed everybody. Whenever he found dead game he ate the eyes first. Once when the raven was like a man he came to a strange camp and told a man to kill his old dog and throw it into the river. The man did so. Then the raven followed the dog down the river and pulled it out and ate its eyes. Thus he went from camp to camp as a deceiver.

THE RAVEN RESTORES THE SUN TO THE SKY

The raven was the cleverest deceiver of all animals, but has one good deed to his credit. At this time, when all animals were men, a bear, who was a bad man, did not want the people of the world to have light, so he took the sun down from the sky and hung it with a string on his neck and kept it covered with his coat. The raven came to his house and pretended to be a friend, and soon married the bear's daughter. They very soon had a child who could walk as soon as born, and grew up in a very short while. The raven told the boy to get the sun from the bear, so the boy cried for it very much and finally the bear allowed the boy to play with it, but watched him carefully. There was no hole in the roof, but the raven made one, and when the bear's attention was away for a moment the boy threw the sun up through the hole into the sky and the bear couldn't get it any more. The raven then ran away and never came back, for the bear would like to kill him.

THE RAVEN AND THE COOT (MUD HEN)

The raven wanted all the birds to look nice and he painted them with their various hues. He painted the coot last. The coot was then in turn to paint the raven, who wanted to be very richly variegated with colors. The coot was painting the raven gorgeously with his right hand, but had charcoal concealed in his left hand. Then, for a joke, while the raven's attention was away, he smeared the raven all over with charcoal. The raven was angry and chased but couldn't catch the coot, so he grabbed and threw a handful of white mud, spattering it over the coot. That is why the coot has white spots on his head and back. The coot flew away and the raven has remained black ever since.

THE WOODPECKER

The woodpecker was a very domestic sort of a man-bird. He used to get married lots of times. When he would get married he would go away from

the people with his wife. After a while he would come back without his wife. He would say that she died. Then he would get another wife. One girl was very smart, so she married him to find out what he did with his wives. They went away together. When he found a good hunting ground he stayed there. Whatever game he got he only gave fat and grease to his wife and ate the meat himself. Whenever she wanted a drink of water he gave her grease to drink. Every time he went hunting he took about ten days, and brought back fat and grease and blueberries and cranberries and all kinds of berries, but no meat. The girl knew by this that he was going to make her so fat that she couldn't walk, for already when she would lie down she could hardly get up. Then, before he went hunting again, at her request, he prepared a dugout on the bank of a creek. She told him she was lonesome and wanted to be where she could see the creek running. This dugout was to be her home while he was away. The door was covered with brush. She told him to make a small, sharp spear for her, so she could keep the mice away with it. As soon as her husband went she took the spear and dug a tunnel from the dugout to the creek for her escape, for she knew he would kill her when she became very fat. She was too fat to walk, so she rolled down to the creek through the tunnel, and stayed in it a whole day, until the fat came off from her. Then she went into the woods and watched till her husband came back. As he approached she saw that he was picking a lot of berries. When he reached the dugout, where the hole was covered with brush for concealment, he ran his spear through the brush so as to kill her; but she wasn't there. Every time he jabbed the spear in and withdrew it he tasted of the point to see if it stuck her. Then he said aloud to himself, "Some spirit must have taken her away." The woman now was sure that he wanted to kill her, so she ran away back to her family. She told them all about it, saying that he killed his wives and ate them, and that he fed them berries to flavor their meat. The man came back then. His wife's mother previously put her in a sack and hid her. He cried much, pretending to be sorry for the death of his wife. He said to the mother, "My wife has died again." Everybody else cried, to deceive him into thinking they believed him. Next day everybody moved again. The old woman gave him a heavy sack to pack along and told him it belonged to his brother-in-law, who needed it. She told him to hang it high on a tree, so the dogs couldn't get it. She told the other men not to help him lift it up. He tried so hard to lift it up that he broke his back-bone.

When the man was injured nobody took care of him. The hunting party went away without him. When they returned and saw that he was sure to die, they let him see his wife, so that he would know that he was found out. His wife was in the sack. Her mother then arrived with other Indian women, untied the sack, and let her out, and she was safe. He died then. They preferred to let him kill himself in this way.

THE ROBIN

The robin had a husband, but she loved another man. She had a family of four—a husband, son, daughter, and self. When she sat on a tree she would laugh. Because she loved another man, she wanted her husband and son to die, so that she and her daughter could live with this man. Every time she sang she would say, "I wish my husband and son would die," then she would laugh. Then she would say, "I wish I and my daughter would live," then she

would laugh. Her husband did whatever she said, and he died. The boy died too. Her husband and son died because she wished them to die. She wished this, so she could get the man she wanted.

The native still chants the words in his own language, meaning, "I wish my husband and son would die," to the tune of a robin whistling. The laugh referred to is the clattering noise which a robin makes when excited.

THE MARTEN

The marten has a white or reddish bridge across his breast. Whenever he was in an Indian camp and they were sitting around the fire eating he always looked hungry and watched every one eat, looking greedily for something for himself. One Indian didn't like being ogled, and threw a chunk of king salmon grease which struck him on the breast and made this bridge-mark.

THE WOLVERENE AND THE TRAVELER

The wolverene is supposed to be the marten's uncle and the wolf's brother-in-law.

One time a man was walking down along a creek. It was winter. He met a wolverene coming up. The wolverene had no sled nor toboggan nor anything except a caribou-skin blanket on him. As soon as the man saw him, the wolverene went into the woods and filled his blanket with brush from spruce trees and made believe he had a load of utensils. His family was following a few miles back. The wolverene sat on his load and made the spruce sticks break. Then he told the man that he had broken his utensils. The man sat on his snow-shoes. The wolverene was bad and reached a long copper hook under the snow to catch hold of the lower snow-shoe and trip him. The wolverene would eat men. The man watched the wolverene because he knew what the wolverene would do. The wolverene, after tripping the man, would kill him with his copper ax. The man put his rabit-skin cap under himself, so when the hook came under him it caught the cap and pulled it out instead of catching his leg. Immediately then the man jumped on the wolverene, grabbed the wolverene's ax, and killed him with his own ax. The man built a camp. He cut off the wolverene's right leg at the shoulder and hung it over the fire to cook. Then he laid the wolverene on his right side to conceal the cut-off shoulder. He put the hook in the wolverene's left hand, giving him the appearance of poking up the fire. This was to deceive the wolverene's family that, coming soon, would think he had something and was cooking it. Then the man hid in the snow about fifty yards away and watched. When the wolverene's family came the young ones tried to wake him up to tell him that the shoulder was cooked, but they could not wake him up. Then they ate up the shoulder, not knowing it was their father's. Then they tried to wake him up more, and found out that he was dead and his shoulder off. Then they knew that they had eaten their father's shoulder. They took their spears and hunted all around for the man. They knew he had come down the river to the camp by his snow-shoe tracks, but he concealed his last tracks. They went about stabbing their spears into the snow to find him. When they came near him he jumped up on his snow-shoes and they all ran after, trying to catch him. The man could not run fast enough, so he wished for a warm wind to come so that the young wolverenes would get overheated and have to throw their coats away. The mother wolverene followed them, and every time one

would throw his coat away she would pick it up and eat it. The man now knew that the young wolverenes had no coats, so he wished that a cold storm would come. Then the storm came and they called to the man, "Partner, come and build a fire for us, because it is cold and we won't kill you." The man started to build a fire. He got wood together and started a fire under it. He didn't want it to burn right away, so he put a little snow on the fire. Then he told the young wolverenes to sit in a row and all blow the fire at once together. As they bent to blow it he struck all of them over the heads with a long pole, killing them all with the one blow.

THE WOLVERENE AND THE HUNTER

The wolverene used often to go out hunting with a man, but every time he would return without his partner. One man decided to go out with him and find out what he did with them. They traveled together all day. Every time they saw a moose track the man wanted to follow it, but the wolverene said, "That's no good; we must go long way to get good hunting." At dark they made a camp. There was plenty of wood about, but wolverene said that he would get a hollow rotten stump and a large squirrel's nest (the kind built on pine-tree branches). The man had stripes about his pants below the knees, made of porcupine quills. The wolverene didn't have any stripes on his pants. They both got wet. The man knew that the wolverene was going to do something bad with the rotten wood. They stretched a pole across the fire and hung their pants on it to dry.

The man turned his pants inside out, so the wolverene did the same way. The wolverene sat on the left of the fire and the man sat on the right, with their pants on their respective sides, so that they would know whose pants each were. They both went to bed without pants on, beside each other. This man was smarter than the wolverene. The man did not sleep, but pretended to. He would snore; then the wolverene would go to get up quietly; then the man would move a little and the wolverene would lie down. The man did not go to sleep, but kept awake till the morning hours, when he was sure the wolverene was asleep. Then the man got up and changed the place of the pants and went back to bed. The wolverene now woke up and took the pants which he thought was the man's. He put them inside the hollow stump and laid the squirrel's nest over it. Then he put it in the fire and burned it. At daylight the man got up. The fire was out, so he built another fire. After that he took his pants down. Then the wolverene got up and said, "Partner, that's my pants." The man said, "No, they are my pants." The wolverene tried to take them away, but the man said, "You haven't any stripes on your pants; there are the stripes, so they're mine." The wolverene was sorry he lost his pants, and said they must have fallen on the fire and burned. The man got lots of small wood, no large pieces, so that it would burn up quickly; then he told the wolverene he would go home to get a pair of pants and come back after him. When he started he got a few hundred yards away; then he called to the wolverene and said, "I have found out now what you do with your partners. I won't come back to you any more." Then the man went home and let the wolverene freeze to death.

A FAMILY ANECDOTE

When Arthur, my interpreter, was a little boy, a lot of youngsters used to get together and some old man or old woman would tell them anecdotes and folk-lore stories. One of them is as follows:

Arthur's mother narrowly escaped death by a big moose once. The moose kills dogs by stamping with the fore feet or kicking with the hind feet. The Indian women went out with the dogs to bring home a lot of cached caribou meat. They dragged the meat over the snow, wrapped up in caribou-skin. A moose appeared at the cache and all the dogs went after him. The women did not want to kill the moose, but they tried to do so because they could not get the dogs away. So they fastened a knife to a stick and tried to spear it. The moose ran toward Arthur's mother and planted both fore feet in front of her but she sat humped up and kept perfectly motionless, and the moose turned away without harming her. If she had moved he would have trampled her to death.

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 56, NUMBER 5

A PRELIMINARY STUDY OF CHEMICAL DENUDATION

BY
FRANK WIGGLESWORTH CLARKE
CHIEF CHEMIST, U. S. GEOLOGICAL SURVEY

(PUBLICATION 1935)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
JUNE, 1910

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

A PRELIMINARY STUDY OF CHEMICAL DENUDATION

By FRANK WIGGLESWORTH CLARKE

CHIEF CHEMIST U. S. GEOLOGICAL SURVEY.

In 1876 the late T. Mellard Reade delivered a remarkable address before the Liverpool Geological Society,[1] which was afterwards separately printed under the title, "Chemical Denudation in Relation to Geological Time." In this address Reade attempted to measure the solvent action of surface waters in England and Wales, and to estimate the amount of dissolved solids annually carried by British rivers to the sea. His conclusion was, in brief, that the annual run-off in England and Wales transported 8,370,630 tons of mineral matter in solution; a quantity which would represent a lowering of the area in question at the rate of one foot in 12,978 years. Evenly distributed, the amount of material so removed from the land amounted to 143.5 tons per square mile of surface, a figure which is surprisingly large. Reade also, from such data as he could obtain, made similar but rough estimates for several European river basins; which, in British tons per square mile, may be tabulated as follows:

Rhone	232.
Thames	149.
Garonne	142.
Seine	97.
Rhine	92.3
Danube	72.7

The average for the entire land surface of the globe he put at 100 tons per square mile, a figure that was not much better than a guess.

About eight years later, in another address before the Liverpool Society, Reade discussed the subject of denudation in the two Americas.[2] For the Mississippi, on the basis of a single old and imperfect analysis, he computed a solvent lowering of the drainage basin at the rate of 120 tons per square mile per annum and for the Amazon his figure was 50 tons. For the St. Lawrence and the River Plate his figures are less explicit, but the St. Lawrence he considers as having a greater chemical activity per square mile than the Mississippi. His former average of 100 tons for all the river basins of the globe he regarded as confirmed.

[1] Proc. Liverpool Geol. Soc., vol. 3, p. 211, 1876.

[2] See "The Evolution of Earth Structures," pp. 255-282. London, 1903.

In 1887 Sir John Murray[1] published a careful discussion of the relations between rainfall and run-off for the entire globe, and incidentally, from the average composition of nineteen rivers he estimated that the saline matter annually carried into the ocean amounted to nearly 5,000,000,000 tons. The rivers taken for this estimate were not named, but must have been in great part European. American data were at that time very meager, and, except for the Nile, there was little material to be had relative to the rivers of Africa and Asia. Reade and Murray both were handicapped by the defectiveness of their data; and yet their conclusions were so important that they have since been made the basis of several attempts to compute geological time. These attempts will be considered in due course later. It is now time to revise some of the fundamental figures.

Within the past year, 1909, two noteworthy reports have been published by the United States Geological Survey.[2] In one of them Dole and Stabler have summarized a great number of observations upon the discharge, drainage areas and salinity of many American rivers, and in the other Dole has given detailed analyses of the waters east of the hundredth meridian. These analyses are numbered by thousands, and in each case the composition of a river water represents the average composition during an entire year. For example, the water of the Mississippi, taken just above New Orleans,[3] was collected daily. Each week the seven samples were mixed and analyzed, and this was repeated regularly during the year. The average of the fifty-two weekly composites gave the mean composition of the river; and, combined with the known discharge, the amount of dissolved matter contributed annually by the entire drainage basin of the Mississippi to the Gulf of Mexico. With evidence of this kind the problem of chemical denudation can now be attacked systematically; and to do so is the purpose of this paper.

First of all, let us try to determine the average composition of the inorganic matter held in solution by river waters, taking into account as far as possible the entire surface of our globe. This is a subject of fundamental importance; for upon its details the estimates of geological time, to which reference has already been made, must be based. For the rivers of the United States the material, although not exhaustive, is adequate; for Europe a fair average can be computed; but beyond these areas the evidence is still very imperfect. Something, however, can be done even with the scanty data which now exist; by comparing the analyses of Asiatic or African waters with those of similar areas elsewhere. The com-

[1] Scottish Geographical Magazine, vol. 3, p. 65, 1887.

[2] Water-Supply Papers 234 and 236.

[3] The river was also studied with great thoroughness at several other points, and so too were its more important tributaries.

position of a river water shows marked climatic features, and the magnitude of the load carried is affected in the same way. In the Temperate Zone, alternations of freezing and thawing tend to break up the rocks and so to render them more easily decomposed by percolating waters. With even moderate humidity the activity of the waters is great, and large amounts of material are transported by them. The rivers of Europe and of the eastern United States are marked by more than the average salinity of flowing waters, and estimates based upon them exclusively are sure to be excessive. In an arid region, although salinity may be high, the run-off is small, and much of an ostensible drainage area will contribute little or nothing to the mineral matter of a stream. Arctic rivers flow to a considerable extent over tundra, which is frozen during the greater part of the year. They, therefore, have comparatively small influence in rock solution, and much of their flow must be mere surface run-off. So also tropical rivers like the Amazon carry relatively light loads in solution, for their courses are largely through swamps and forests where the soil, unreplenished by fresh rock decomposition, has been leached for centuries and so deprived in great part of its soluble matter.

To illustrate some of these differences in the composition of stream waters a few typical examples may be taken. The analyses represent, in ionic form, the percentage composition of the dissolved mineral matter, and under the caption of *denudation factor* I give the number of metric tons annually removed in solution from each square mile of a drainage basin. The following waters have been chosen for this purpose:

A. The St. Lawrence at Ogdensburg. Annual average as given by Dole, the denudation factor by Dole and Stabler.[1]

B. The Mississippi at New Orleans. Annual average; Dole and Stabler. Analyses by J. L. Porter.

C. The Rio Grande at Laredo, Texas. Annual average as given by Dole from analyses by W. H. Heileman. Denudation factor from Dole and Stabler.

D. The Colorado at Yuma. Mean annual composition as given by Forbes and Skinner. Bull. 44, Arizona Agric. Exper. Station, 1902. Denudation factor by Dole and Stabler.

E. The Amazon. A single analysis by P. F. Frankland, used by Reade. Two analyses by Katzer give lower salinities, and, therefore, a smaller transport of material. For the total discharge of the river I have taken the data given by Murray in the memoir already cited.

[1] Dole and Stabler's figures for denudation are given in tons of 2000 lbs. They are here reduced to metric tons of 2205 lbs. The analyses are recalculated to two decimal places.

F. The Uruguay. Mean of two analyses by Kyle and Schoeller.[1] Denudation computed from Murray's figures for the discharge and drainage area.

G. The Nile. Annual average as shown by Letheby's analyses.[2] Drainage area from Murray. Total dissolved matter, 20,772,400 metric tons per annum according to Chélu.[3]

	A.	B.	C.	D.	E.	F.	G.
CO_3	45.69	25.21	11.55	12.02	34.75	22.91	36.50
SO_4	9.98	15.36	30.09	28.61	7.37	5.02	17.44
Cl	5.82	1.60	21.65	19.52	3.35	2.87	4.47
NO_3	.22	6.21	....	....	....	2.75	trace
Ca	23.45	20.49	13.73	10.35	21.12	9.91	20.10
Mg	5.45	5.38	2.03	3.14	2.57	2.91	4.01
Na	4.77	9.33	14.79	19.75	1.94	4.84	3.04
K			.87	2.17	2.31	1.56	7.97
SiO_2	4.99	7.04	3.83	3.04	18.80	45.27	6.47
Al_2O_3, Fe_2O_3	.52	.38	.47	....	7.29	1.96	....
	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Denudation factor....	105.	98.	22.7	46.2	53.	50.4	16.

These analyses tell a consistent story. The St. Lawrence represents a humid area, and every square mile of it contributes something to the salinity of the waters. Hence a solvent activity of 105 tons per square mile. The Mississippi is a blend of waters from humid regions on the east and arid or semi-arid plains to the west, and its load is, therefore, proportionately lowered. The Colorado and Rio Grande are typical of areas which are largely arid, and many square miles of their nominal drainage basins add nothing to the saline burdens. The Amazon and the Uruguay show the low salinity of the tropical forest regions, and the Nile flows for a thousand miles of its course through a desert. The saline matter of the Nile comes in great part from the regions south of Khartoum. It has no tributaries worth considering north of the Atbara.

Even on the purely chemical side the analyses are instructive. The water of the St. Lawrence is essentially a calcium carbonate solution; in the Colorado and Rio Grande sulphates and chlorides predominate, and calcium is relatively low; the Mississippi has an intermediate character. As a rule the waters from arid regions resemble the Colorado; those from humid areas are more like the St. Lawrence. This, of course, is not an absolute rule, but it holds fairly well in a broad general way. It is a distinct aid in discussing the larger problems of chemical denudation.

[1] See "Data of Geochemistry," Bull. 330 U. S. Geol. Surv., p. 75.
[2] Ibid., p. 82.
[3] Le Nil, l'Egypt, le Soudan. Paris, 1891.

In an essay of this kind it is impracticable to give all the details of the discussion. It is enough to indicate their nature briefly, for the results can only be approximations to the truth, with no claims to finality. Taking the several continents in order, the composition of their waters tributary to the ocean may be estimated as follows:

For the United States the data given by Dole and Stabler in Water-Supply Papers 234 and 236 are taken, together with those of Forbes and Skinner for the Colorado. The river basins considered are the St. Lawrence, Hudson, Delaware, Susquehanna, Potomac, James, Roanoke, Neuse, Cape Fear, Pedee, Santee, Savannah, Altamaha, Apalachicola, Alabama, Pearl, Mississippi, Brazos, Colorado of Texas, Rio Grande, Colorado of Arizona, and Sacramento.[1] Each average composition is roughly weighted proportionally to the total amount of dissolved matter transported by the river in a year, and in that way the mean for the United States is obtained; a mean which is not likely to be much altered by any future analyses. According to Dole and Stabler the quantity of saline matter carried from these basins is 87 short tons or about 79 metric tons per square mile annually.

For the rest of North America only an estimate is possible. Eleven analyses of river waters from the Saskatchewan system, one from the Yukon, and one from the Ottawa, give a mean composition of the dissolved matter resembling that of the St. Lawrence. So much for British North America and Alaska. For Mexican and Central American waters no data are at hand, but it is probable that they would be, for northern Mexico, at least, similar to those of Arizona, New Mexico and Texas. That is, the waters north of the United States and south of it would vary from the mean obtained for the United States, in opposite directions, and so tend to balance each other. In short, the average for the United States will probably represent fairly well the average for the entire continent. If we assume that six millions of square miles of North America lose 79 metric tons in solution per square mile per annum, and that the composition of the saline matter so transported is that found for the United States alone, we shall not be very far from the truth.

Analyses of South American river waters are not numerous. For the great rivers north of the Amazon I have found no data at all. We may assume, however, that they will resemble the Amazon in their general features, and taking the analysis and denudation factor of that river as typical, we can regard its composition as representing the waters of about three millions of square miles. Figures for the Uruguay, draining 151,000 square miles, I have already given. There is also an analysis by

[1] Average of 20 composite analyses of 10 daily samples each, furnished by Mr. R. B. Dole. Not in Dole's memoir.

Schoeller of water from the Rio Negro, which I assign equal weight with that of the Uruguay. The data for the River Plate are unsatisfactory, for the analyses suggest a strong probability of tidal contamination. South of the Plate the streams show a resemblance to those of our own southwestern areas, of which the Colorado is the type. I have averaged together twelve analyses, including two Chilean rivers, and so obtained the results given in the following table. In combining the analyses they are weighted as indicated at the foot of each column.

	Amazon.	*Uruguay.*	*Negro.*	*12 rivers.*	*Weighted mean.*
CO_3	34.75	22.91	39.10	19.82	32.48
SO_4	7.37	5.02	1.23	17.22	8.04
Cl	3.85	2.87	4.43	19.14	5.75
NO_3	....	2.75	1.95	2.65	.62
Ca	21.12	9.91	17.82	10.77	18.92
Mg	2.57	2.91	1.96	2.82	2.59
Na	1.94	4.84	10.24	21.01	5.03
K	2.31	1.56	....	1.67	1.95
Fe_2O_3, Al_2O_3....	7.29	1.96	1.52	.36	5.74
SiO_2	18.80	45.27	21.75	4.54	18.88
	100.00	100.00	100.00	100.00	100.00
Weight	12.	1.	1.	2.	

This mean I shall assume as representing the waters of four millions of square miles, with a denudation factor, as shown by the Amazon, Uruguay, and, for comparative purposes, the Colorado also, of 50 tons per square mile annually. This is only a rough estimate, but it is a probable one and the best I can make with the existing material. The Amazon dominates the combination, just as the Mississippi does in the United States. Data relative to the Magdalena, Orinoco, Demerara, San Francisco, and Plate, the latter at some point far above the possibility of tidal contamination, are much to be desired.

Analyses of European river waters are abundant, but rarely numerous enough for any one stream to give conclusive evidence as to its denudation value. I have, however, averaged together 300 analyses of European lakes and rivers,[1] first by groups and then weighting each group proportionally to its drainage area. In that way I have obtained a highly probable mean for the composition of the waters, which will appear in a table to be given later. The denudation factor I can only estimate roughly. According to Geikie[2] the Thames carries in solution past Kingston 548,230 British or 556,930 metric tons dissolved inorganic matter annually. The drainage area is 6100 square miles; hence a denudation factor of 91.3 tons; an estimate much lower than that of Reade. For the Meuse above Liége, the

[1] Not 300 rivers. Some streams, like the Elbe and Danube, are represented by numerous analyses.
[2] Text-book of Geology, 4th ed., vol. 1, p. 489.

figures published by Spring and Prost[1] give a factor of 139 tons per square mile. Reade's estimate for all Europe is 100 tons, and that seems to be fairly probable. For Europe, then, I shall assume that 3,000,000 of square miles suffer solvent denudation at the rate of 100 tons per mile, a figure which is much like that of the St. Lawrence. Europe is generally well-watered, and its waters have all the characteristics of those from the humid areas of the United States. In the latter the denudation factor is lowered by the arid regions of the southwest.

The African material is very scanty. In addition to the figures already cited for the Nile, with a drainage area estimated at 1,293,050 square miles, I have found only analyses of three small Algerian rivers which exhibit all the peculiarities of waters from other semi-arid districts. Ignoring the latter I shall estimate that 1,500,000 square miles in Africa are represented by the Nile with the denudation factor of 16 tons. I shall also assume that 6,500,000 square miles are fairly equivalent in character to South America, with the same composition of the waters and the same denudation factor of 50 tons. The desert regions, like the Sahara, of course count for nothing. Analyses of water from the Niger, Congo, Orange, and Zambesi are much needed.

The data relative to Asiatic waters are still more defective. I have found analyses by Schmidt of water from Lake Baikal and the river Om in Siberia, and one by Nicholson of the Mahanuddy in India. Waters of saline lakes, not tributary to the ocean, I of course leave out of account. The water of Lake Baikal is closely similar in character to that of the Yukon and St. Lawrence; that of the Mahanuddy more resembles the waters of tropical South America. With these feeble clues I can only make a very rough estimate for Asia, as follows: Assume three millions of square miles to average like Europe; three millions like the United States; and one million like South America. Large areas in Asia obviously are left out of consideration; the Caspian depression, the deserts of Central Asia, and the Arabian peninsula. The streams which reach the sea from Arabia are too insignificant to carry any weight in the general discussion. For Australia I have no data.

To sum up, the crude figures upon which to base further discussion are as follows, beginning with a summary of the denudation values for each continent:

North America	6,000,000	sq.	miles,	at	79	tons	474,000,000 tons
South America	4,000,000	"	"	"	50	"	200,000,000 "
Europe	3,000,000	"	"	"	100	"	300,000,000 "
Asia	7,000,000	"	"	"	84	"	588,000,000 "
Africa	8,000,000	"	"	"	44	"	352,000,000 "
Total							1,914,000,000 "

[1] Ann. Soc. Géol. Belg., vol. 11, p. 123.

The total area accounted for is 28,000,000 square miles, with a mean solvent denudation of 68.4 tons. The incompleteness of the figures is due to the fact that large areas of the earth's land surface either do not drain into the ocean, or, as in the cases of Arabia, the coast of Peru, etc., contribute little or nothing to it. There is, of course, local denudation in areas like the Great Basin of the United States and the Caspian depression; but that does not fall within the scope of the present discussion. Furthermore, the circumpolar regions such as Greenland and the Antarctic continent have no large rivers, and must be left out of account. The total land area to be considered, that is, the area which contributes to the salinity of the ocean, is, according to Murray, 39,697,400 square miles, or 40,000,000 in round numbers. Assuming that the figures so far given for 28,000,000 square miles represent a fair average, the total amount of saline matter carried into the ocean by the river drainage of the world is 2,735,000,000 metric tons, an estimate only a little more than half that given by Murray.

The composition of the saline matter thus carried into the ocean is given in the next table. The averages for Asia and Africa are made up in the manner already indicated: the final general mean roughly weights the individual means proportionally to the number of tons given in the last column of the foregoing table:

	N. America.	*S. America.*	*Europe.*	*Asia.*	*Africa.*	*General mean.*
CO_3	33.40	32.48	39.98	36.61	32.75	35.15
SO_4	15.31	8.04	11.97	13.03	8.67	12.14
Cl	7.44	5.75	3.44	5.30	5.66	5.68
NO_3	1.15	.62	.90	.98	.58	.90
Ca	19.36	18.92	23.19	21.23	19.00	20.39
Mg	4.87	2.59	2.35	3.42	2.68	3.41
Na ..... }	9.23	5.03	4.32	6.42	4.90	6.40
K ..... }		1.95	2.75	1.54	2.35	1.51
R_2O_3	.64	5.74	2.40	1.96	5.52	2.75
SiO_2	8.60	18.88	8.70	9.51	17.89	11.67
	100.00	100.00	100.00	100.00	100.00	100.00
Weight	10.	4.	6.	11.	7.	

The final mean, regardless of possible corrections, is curiously near the average figures for three great rivers, the Mississippi, Amazon, and Nile. It is probably rather high in silica, but on the whole it is as near to the truth as can be determined from the existing data. The greater rivers of Africa and Asia are yet to be studied, and much more should be done in South America. In the analyses reported by Dole, sodium and potassium are rarely discriminated, and hence the two radicles are given together as sodium alone. This error, however, is compensated by the excessive and evidently erroneous determinations of potassium in the Nile

and in some European rivers, so that the final figures are not far out of the way. Dr. Chase Palmer, working in co-operation with Dole in the study of American waters, made more than one hundred careful determinations of the ratio between sodium and potassium in over forty rivers, and found it to be very nearly 4.2 to 1. This ratio is practically identical with that given in my general mean, namely, 4.24 to 1, and the latter is, therefore, satisfactory.

In order to apply the foregoing averages to the discussion of either chemical denudation or geological time, certain other data are needed. Some of these are general, others are of the nature of minor corrections. Professor J. Joly,[1] in order to determine the age of the ocean, divided its total content of sodium by the amount annually carried into it by rivers, and so deduced an uncorrected value of 97,600,000 years. The computation is simple enough, and is based upon the fact that sodium is less removed from the waters than other substances; if, indeed, it is appreciably removed at all. Calcium and magnesium are precipitated as carbonates; potassium is absorbed by clays, silica goes to form siliceous oozes. Sodium alone, among the basic elements, tends to accumulate in the ocean with little loss, and so to give some indication of its geological age.

Joly, however, employed data of a defective character. Murray's estimate of the sodium in rivers was taken, which, as we have seen, needs serious modification. For the volume of the ocean he combined Wagner's, or rather Karstens', estimate of its area with Murray's figure for its average depth, and used Dittmar's analyses for the proportion of sodium in it. The last datum is satisfactory; the others need revision.

The best estimate of the volume of the ocean is probably that of Karstens,[2] 1,285,935,211 cubic kilometers. This, with Murray's figure for the mean density, 1.026, gives the ocean a mass of $1{,}319{,}650 \times 10^{11}$ metric tons. Assuming an average salinity of 3.5 per cent., the total saline matter in the ocean amounts to $46{,}188 \times 10^{12}$ tons; which, according to Dittmar's analyses, is distributed as follows:

	Per cent.	*Metric tons* $\times 10^{12}$.
Cl	55.292	25,538.
Br	.188	86.8
SO_4	7.692	3,553.
CO_3	.207	95.6
Na	30.593	14,130.
K	1.106	510.8
Ca	1.197	552.8
Mg	3.725	1,721.
	100.000	46,188.0

The small traces of other substances in the ocean only represent insignificant corrections to these figures.

[1] Trans. Roy. Soc. Dublin (2), vol. 7, p. 23, 1899. Rep. British Asso. Adv. Sci., 1900, p. 369.
[2] Eine neue Berechnung der mittleren Tiefen der Oceane. Inaug. Diss., Kiel, 1894.

From the figures previously given, for the average composition of river waters and the total chemical denudation of the globe, 175,040,000 metric tons of sodium are annually discharged into the sea. The crude quotient,

$$\frac{\text{Na in ocean}}{\text{Na in rivers}} = 80{,}726{,}000;$$

the time in years needed to furnish the entire amount of marine sodium; assuming a sodium-free ocean at the start and a uniform rate of supply throughout all geological time. Any probable change in either of these assumptions will reduce the quotient, although other considerations may tend to increase it. The first correction to be examined operates in the latter direction.

A part of the sodium found in the discharge of rivers is the so-called "cyclic sodium"; that is, sodium in the form of salt lifted from the sea as spray and blown inland to return again to its source in the drainage from the land. Near the sea coast this cyclic salt is abundant; inland its quantity is small. For example, by careful analyses of rainfall, continued over long periods of time, the following amounts of cyclic salt have been determined. The figures represent pounds per acre per annum of sodium chloride.

Locality.	*NaCl in rain.*
Rothamsted, England	24.
Cirencester, England	36.1
Perugia, Italy	37.95
Barbados	193.

In central Massachusetts, according to Mrs. Ellen S. Richards,[1] the cyclic salt, at distances of 50 to 100 miles from the coast, amounts to 23.2 pounds per acre per annum.

The Rothamsted figures are very suggestive. Rothamsted lies in the Thames valley, and if its figure for sodium chloride in rain be taken as a fair average for the entire drainage basin, 6100 square miles, the quantity there brought down amounts to 41,732 British tons annually, or 16,445 tons reckoned as sodium alone. Analyses of the Thames give sodium as 3.26 per cent of the total inorganic matter in solution, or, in terms of the discharge already cited, 17,872 tons. Here the cyclic sodium is nearly as much as the total amount carried by the stream; but of course one cannot assume that all of the cyclic portion finds its way back to the ocean in any brief or relatively brief time. It is enough to say that in the British islands the correction for cyclic salt must be large; while for the great continental rivers like the Mississippi, St. Lawrence, Amazon, Danube, or Nile it is very much smaller.

[1] Private communication. For the other figures, see Data of Geochemistry, p. 47.

It is difficult, with existing data, to evaluate the correction for cyclic sodium with any great approach to accuracy. It probably varies for different regions, but from the well-known "chlorine maps" of New England and New York, with their "isochlors," a good estimate for the United States can be made. This part of the work has been done by Dr. Becker, whose discussion of the subject appears elsewhere. Another, cruder estimate may be made as follows: If we assume with regard to the United States that the salt brought down in rain is represented by the Rothamsted figures for a strip 100 miles wide following the coast line, an area, roughly, of about 450,000 square miles, the quantity of sodium thus found amounts to 1,231,300 metric tons. Regarding the correction for the interior of the United States as zero, an assumption which is justified by a study of the isochlors, the final result may be obtained as follows: The total sodium carried by the rivers of the United States to the sea, after correcting the crude value already given in the table of analyses by Palmer's value for the Na-K ratio, amounts to, roughly, 17,500,000 tons. The cyclic sodium is only 7 per cent. of the latter quantity, whereas Joly allows 10 per cent., but the smaller figure is probably a maximum. Deducting 7 per cent. from the total sodium carried by the rivers, 175,040,000 metric tons per annum, the remainder is 162,787,200 tons; which, divided into the sodium of the ocean gives a quotient of 86,800,000 years. Joly's correction of 10 per cent. is very nearly equivalent to the assumption that the entire run-off of the globe, 6524 cubic miles, according to Murray, carries on an average one part per million of chlorine. The chlorine maps, so far as they have been made, show this figure to be excessive.

The foregoing correction for "cyclic salt" is, however, not final. It has already been suggested that the wind-borne salt is only in part restored to the ocean, at least within reasonable time. Some of it is retained by the soil, if not permanently, at least rather tenaciously; and the portion which falls into depressions of the land may remain undisturbed almost indefinitely. In arid regions, like the coasts of Peru, Arabia, and parts of western Africa, a large quantity of cyclic salt must be so retained in hollows or valleys which do not drain into the sea. Torrential rains, which occur at rare intervals, may return a part of it to the ocean, but not all. Some writers, like Ackroyd[1] for example, have attributed the saline matter of the Dead Sea to an accumulation of wind-borne salt; an assumption which contains elements of truth, but is probably extreme. A more definite, but equally striking instance of the sort is furnished by the Sambhar salt lake in northern India, as studied by Holland and Christie.[2] This lake, situated in an enclosed drainage basin of 2200 square miles and

[1] Chem. News, vol. 89, p. 13, 1904.
[2] Records Geol. Survey India, vol. 38, p. 154, 1909.

over 400 miles inland, appears to receive the greater part, if not all of its salt from dust-laden winds which, during the four hot, dry months, sweep over the plains between it and the arm of the sea known as the Rann of Cutch. Analyses of the air during the dry season, showed a quantity of salt so carried which amounted to at least 3000 metric tons over the Sambhar lake annually, and 120,000 tons into Rajputana. These quantities are sufficient to account for the accumulated salt of the lake, which the authors were unable to explain in any other way.

Examples like this of the Sambhar lake are of course exceptional. In a rainy region salt dust is quickly dissolved and carried away in the drainage. Only in a dry period can it be transported as dust from its original point of deposition to points much further inland. It appears, however, that some salt is so withdrawn, at least for an indefinitely long time, from the normal circulation, and should, if it could be estimated, be added to the amount now in the ocean. Such a correction, however, would doubtless be quite trivial, and, therefore, negligible; and the same remark must apply to all the visible accumulations of rock salt, like those of the Stassfurt region, which were once laid down by the evaporation of sea water. The saline matter of the ocean, if concentrated, would represent a volume of over 4,800,000 cubic miles; a quantity compared with which all beds of rock salt become insignificant.

But although the visible accumulations of salt are relatively insignificant, it is possible that there may be quantities of disseminated salt which are not so. The sedimentary rocks of marine origin must contain, in the aggregate, vast amounts of saline matter, widely distributed, but rarely determined by analysis. These sediments, laid down from the sea, cannot have been completely freed from adherent salts, which, insignificant in a single ton of rock, must be quite appreciable when cubic miles are considered. The fact that their presence is not shown in ordinary analyses merely means that they were not sought for. Published analyses, whether of rocks or of waters, are rarely complete, especially with regard to those substances which may be said to occur in "traces."

It is perhaps not possible to estimate the quantity of this disseminated salt, and yet a maximum limit may be assigned to it. In a former publication [1] it was shown that 84,300,000 cubic miles of the average igneous rock would, upon decomposition, yield all the sodium of the ocean and the sedimentaries. This estimate involved the maximum, not the mean salinity of the ocean, and also a different value for the mass of the latter from that now adopted. In order to revise the estimate, which must be considerably reduced, it is desirable first to consider the average composition of the two classes of rocks, especially since the data are applicable to other phases of the discussion than that now under consideration.

[1] Data of Geochemistry, pp. 28-29.

For the average composition of the igneous rocks there are two principal estimates: Clarke's,[1] based upon analyses made in the laboratories of the United States Geological Survey alone, and Washington's,[2] which includes analyses from all parts of the world. These two composites, reduced to 100 per cent. and condensed by union of minor and unimportant constituents, assume the following form:

	Clarke.	*Washington.*	*Mean.*
SiO_2	59.99	57.78	58.88
Al_2O_3	15.04	15.67	15.36
Fe_2O_3	2.59	3.31	2.95
FeO	3.34	3.84	3.59
MgO	3.89	3.81	3.85
CaO	4.81	5.18	4.99
Na_2O	3.41	3.88	3.65
K_2O	2.95	3.13	3.04
H_2O	1.92	1.78	1.85
Minor constituents..	2.06	1.62	1.84
	100.00	100.00	100.00

In the mean the Survey analyses, of which many are included in Washington's average, evidently receive double weight.

When the average igneous rock decomposes, it loses some substances by leaching, and gains others, such as oxygen, water, and carbon dioxide. The products of decomposition, as nearly as can be estimated, are 5 per cent. limestones, 15 per cent. sandstones, and 80 per cent. the residues which consolidate to form slates and shales. The composite analyses of sedimentary rocks, made in the laboratory of the United States Geological Survey,[3] are given in the next table, with their weighted average recalculated to 100 per cent.

	Shales.	*Sandstones.*	*Limestones.*	*Weighted mean.*
SiO_2	58.38	78.66	5.19	58.51
Al_2O_3	15.47	4.78	.81	13.07
Fe_2O_3	4.03	1.08	.54	3.40
FeO	2.46	.30	....	2.00
MgO	2.45	1.17	7.90	2.52
CaO	3.12	5.52	42.61	5.42
Na_2O	1.31	.45	.05	1.12
K_2O	3.25	1.32	.33	2.80
H_2O	5.02	1.64	.77	4.28
CO_2	2.64	5.04	41.58	4.93
Minor constituents.....	2.33	.45	.31	1.95
	100.46	100.41	100.09	100.00
Weight	80.	15.	5.	

[1] U. S. Geol. Surv., Bull. 419, pp. 4-9, 1910.
[2] U. S. Geol. Surv. Prof. Paper, No. 14, p. 106, 1903.
[3] U. S. Geol. Surv. Bull. 419, p. 10.

In the ocean, as previously shown, there are 14130×10^{12} metric tons of sodium. This amount would be supplied by the *complete* decomposition of 48,225,000 cubic miles of an igneous rock having the composition shown by Clarke's average, or 42,385,000 cubic miles on the basis of Washington's figures. Some sodium, however, is retained by the sedimentary rocks, for the reason that decomposition is rarely, if ever, perfect. Fragments or particles of feldspar are especially common in the sedimentaries. On comparing the average composition of the latter with that of the igneous rocks, assuming that alumina has remained constant, the following ratios appear:

	Clarke.	*Washington.*
Na_2O retained, per cent.....	1.29	1.38
Na_2O lost, per cent.....	2.12	2.50
	3.41	3.88

Hence, for the total volume of igneous rock needed to furnish all the sodium of the ocean and of the sediments, assuming that the sodium lost represents the marine portion, we have:

From Clarke's average.....	77,570,000 cubic miles
From Washington's average.	65,782,000 " "

These figures correspond, respectively, to a shell of igneous rock, completely enveloping the globe, 2050 feet thick in one case, or 1740 in the other. For present purposes the higher estimate will be taken, in order that the deductions may be maxima.

If, now, the sedimentary rocks were of the same volume as the igneous rocks from which they were derived, and if the sandstones form 15 per cent. of the 77,570,000 cubic miles, the bulk of the latter will be, very roughly, 10,635,500 cubic miles. The assumptions thus made are of course not exact, but they will suffice for the computations now in hand. The errors are negligible, so far as present needs are concerned. Assume further that the sandstones, the most porous of the rocks, contain an average pore space of 20 per cent., or 2,127,100 cubic miles, and that all of it was once filled by sea water, representing 99,861,000,000,000 metric tons of sodium. If all of that sodium were now present in the sandstones, and erosion began at the rate now assigned to the rivers, namely, 175,040,000 tons of sodium annually, the entire accumulation would be removed in 570,000 years. This, compared with the estimate already reached for geological time, is an almost negligible quantity. Even if the entire volume of the sedimentary rocks carried the same proportion of sodium as is here assigned to the sandstones, it would be exhausted in about 3,800,000 years. The correction for disseminated salt is, therefore, in all probability small, and not likely to exceed 1 per cent.

The foregoing calculations, so far as geologic time is concerned, imply the assumption that rivers add sodium to the sea at an average uniform rate, slight accelerations being offset by small temporary retardations. This subject is to be discussed by Mr. G. F. Becker; but one phase of it demands consideration here. The present rate of discharge has been hastened during modern times by human agency, and that acceleration may be important to take into account. The sewage of cities, the refuse of chemical manufactures, etc., is poured into the ocean, and so disturbs the rate of accumulation of sodium quite perceptibly. The change due to chemical industries, so far as it is measurable, is wholly modern, and that due to human excretions is limited to the time since man first appeared upon the earth. Its exact magnitude, of course, cannot be determined; but its order seems to be measurable, as follows:

According to the best estimates, about 14,500,000 metric tons of common salt are annually produced, equivalent to 5,700,000 tons of sodium. If all of that was annually returned to the ocean, it would amount to a correction of about 3.25 per cent. on the total addition of sodium to the sea. The fact that much of it came directly or indirectly from the ocean in the first place is immaterial to the present discussion; the rate of discharge is affected. All of this sodium, however, is not returned; much of it is permanently fixed in manufactured articles. The total may be larger, because of other additions, excretory in great part, which cannot be estimated; but we may assume, nevertheless, a maximum of 3 per cent. as the correction to be applied. Allowing 7 per cent., as already determined, to cyclic or wind-borne sodium, and 1 per cent. to disseminated salt of marine origin, the total correction is 11 per cent. This reduces the 175,040,000 tons of river sodium to 155,785,600 tons, and the quotient representing crude geologic time becomes 90,700,000 years.

The corrections so far considered are all in one direction, and increase, by a roughly evaluated amount, the apparent age of the ocean. Other corrections, whose magnitudes are more uncertain, tend to compensate the former group. The ocean may have contained primitive sodium, over and above that since contributed by rivers. It receives some sodium from the decomposition of rocks by marine erosion, which is estimated by Joly to be a correction of less than 6 per cent. and more than 3 per cent. on the value assigned to geologic time. Sodium is also derived from volcanic ejectamenta, from "juvenile" waters, and possibly from submarine rivers and springs. The last possibility has been considered by Sollas,[1] but no numerical correction can be devised for it. These four sources of sodium in the sea may be grouped together as non-fluviatile, and reduce the numerator of the fraction which gives the age of the ocean. Whether

[1] Presidential address, Quar. Journ. Geol. Soc., May, 1909.

they exceed, balance, or only in part compensate the other corrections it is impossible to say. The rough quotient at first obtained, 80,726,000 years, is as probable as any other value that might be chosen. That value, as will be shown by Mr. Becker's calculations, is certainly a maximum. It represents, in its essential features, Joly's method of computing the age of the ocean, but takes, with one minor exception, no account of changes of rate in the annual additions to the marine salinity. Joly's final estimate of the age is 90,000,000 years, with a possible increase of 6 per cent. due to a revision of the mass of the ocean.

Reade, in the investigation cited at the beginning of this paper, estimated the solvent denudation of England and Wales at 143.5 British, or 146 metric tons per square mile per annum, or one foot in 12,978 years. The smaller denudation factors now found lead to different results. For the United States, excluding the Great Basin, the factor of 79 tons gives, for a lowering of one foot, 23,948 years. For South America the figures are 50 tons and 37,751 years; for Europe, 100 tons and 18,875 years and for the Nile Valley, 16 tons and 93,924 years. For the 40,000,000 square miles of the globe, which drain into the ocean, the average values are 68.4 tons and 27,660 years, estimates that are subject to large corrections, which Reade did not take into consideration. The foregoing figures only apply to his method of computation.

On critical examination of the data it is clear that the total apparent amount of solvent denudation is not a true measure of rock decomposition. In the general mean of all the river analyses now under discussion, 0.90 per cent. of NO_3 and 35.15 per cent. of CO_3 appear. The NO_3 came entirely or practically so from atmospheric sources; the CO_3 was derived partly from the atmosphere and partly from the solution of limestones. Dealing now only with the existing discharge of rivers, we must subtract these atmospheric additions from the total annual load of dissolved inorganic matter, before we can compute the real amount of rock denudation.

The land surface of the earth is covered, nearly enough for present purposes, by 75 per cent. of sedimentary and 25 per cent. igneous and crystalline rocks;[1] and it is on or near this surface that the flowing waters act. The limestones, as shown in my former discussion, constitute only one-twentieth of the sediments, or 3.75 per cent. of the entire area; but the proportion of carbonates derived from them must be very much larger. The composite and average analyses of rocks give, for lime, 4.81 per cent. in the igneous, and 5.42 in all the sedimentaries, equivalent to 3.78 and 4.26 per cent. of CO_2 respectively. Assuming that all the surface rocks yield lime at an equal rate, which is obviously not quite true, and multiplying these figures by the areas represented as 1 to 3, the

[1] Estimate by A. von Tillo, actually 75.7 and 24.3.

relative proportions of the CO_3 radicle become 3.78 : 12.78, or 1 : 3.4 nearly. The last figure should be higher, because of the more rapid solution of the limestones, but if we accept the ratio as it stands we may use it to determine the approximate proportions of the CO_3 radicle derived from limestones and from the atmosphere acting upon crystalline rocks. On this basis, 8 per cent. of CO_3 should be deducted from the percentage in the river waters, together with the 0.9 per cent. of NO_3. Making the subtraction from the total river load of dissolved matter, 2,735,000,000 tons, there remains 2,491,585,000 tons, or about 62.3 tons per square mile on the average, for the 40,000,000 of square miles of land which are assumed to drain into the ocean. This implies a lowering of the land by solvent denudation at the rate of one foot in 29,941 years, or 30,000 in round numbers. The last estimate may be subject to large future corrections, but probably it is correct to within 10 per cent.

It is possible, with the data now in hand, to take still another step and determine approximately the quantity of *chemical* sediments annually precipitated in the ocean. For this purpose we may first, knowing the average composition of river waters, and also their total load of dissolved inorganic matter, compute the actual amount of each radicle poured into the ocean in one year. The total amount so added is 2,735,000,000 metric tons, distributed as follows:

CO_3	961,350,000	tons
SO_4	332,030,000	"
Cl	155,350,000	"
NO_3	24,614,000	"
Ca	557,670,000	"
Mg	93,264,000	"
Na	175,040,000	"
K	41,299,000	"
R_2O_3	75,213,000	"
SiO_2	319,170,000	"
	2,735,000,000	"

If, from each of these quantities we subtract the amount annually retained in solution by the sea, the difference will represent the amount precipitated. To do this, an assumption must be made as to the age of the ocean; but whatever probable figure is thus assumed, the results will be of the same order of magnitude. For example, the ocean contains 552.8×10^{12} metric tons of dissolved calcium, which quantity, divided by the assumed age, gives the annual increment. If the age of the ocean is 100,000,000 years, the annual addition of calcium is 5,528,000 tons; if only 50,000,000 years it is 11,056,000 tons. Subtracting these quantities from the total calcium of the river waters the remainders become 552,142,000 and 546,614,000 tons respectively, the difference being much less

than the actual uncertainties of the computation. If, for the sake of uniformity, we take as the crude age of the ocean the quotient first obtained, 80,726,000 years, the chemical precipitates are represented by the following annual quantities:

SO_4	288,017,000	metric	tons
Ca	550,822,000	"	"
Mg	71,945,000	"	"
K	34,971,400	"	"
R_2O_3	75,213,000	"	"
SiO_2	319,170,000	"	"

Combined, the radicles thus precipitated in the ocean, yield the following substances:

Gypsum, $CaSO_4 . 2H_2O$	516,020,000	metric	tons
Calcium carbonate, $CaCO_3$	1,077,030,000	"	"
Magnesium carbonate, $MgCO_3$	249,587,000	"	"
Limonite,[1] $2Fe_2O_3 . 3H_2O$	87,505,000	"	"
Silica, SiO_2	319,170,000	"	"

The potassium remains unaccounted for. Part of it is taken up by the clay-like substances in the oceanic silts, and part goes to form glauconite; but it is not worth while to speculate upon the relative proportions of potassium withdrawn by these two processes from solution.

The figures given above for the quantities of the five chemical precipitates annually deposited in the ocean can, of course, make no pretense to accuracy. They are merely rough approximations to the truth, but they tell something of the relative magnitudes. Even if we knew precisely the age of the ocean, it would not be practicable to reckon backward and so to determine the total mass of deposits formed during geological time. The figures tell us what is happening to-day, but are inapplicable to the past. The reason for this statement is, that apparently the different deposits have formed at different rates. In the beginning of chemical erosion fresh rocks were attacked, and relatively more silica and less lime passed into solution. At present, limestones, laid down in previous geologic ages, are being dissolved, and calcium is added to the ocean more rapidly than in pre-Cambrian times. This is not mere speculation. A study of river waters with reference to their origin, whether from crystalline or sedimentary rocks, fully justifies my assertions.

The vexed question as to the source of oceanic chlorine, I have so far left out of consideration. Dr. Becker has shown that volcanic agencies are adequate to account for it. Some, however, may have come from ferrous chloride, lawrencite, a compound which is common in meteoric irons. If our planet is analogous to a great meteorite, lawrencite must

[1] Assuming R_2O_3 to be all Fe_2O_3. It is certainly, in part, Al_2O_3.

exist in it, and was possibly, in early geologic periods, leached into the ocean in large amounts. Its iron would be precipitated by the alkaline carbonates of river waters, while chlorides of the alkaline metals were produced. Dr. Becker, however, inclines to regard deeply buried lawrencite as the origin of volcanic chlorine, and it is possible that the great mass of this ferrous chloride underlay the specifically lighter primeval rocks. It is also conceivable that the earliest crystalline rocks were richer in easily decomposable minerals like sodalite than the surface rocks of to-day, and, therefore, added more chlorine to the ocean than is leached into it now. Such rocks, if they existed, would be more rapidly eroded than the less soluble species, and, consequently, less abundant at the present time. A primitive atmosphere, rich in chlorine, and an ocean of weak hydrochloric acid may have once existed, but their assumption is by no means necessary in order to account for the known facts.

This memoir is entitled "A Preliminary Study of Chemical Denudation." It has been written in order to make existing data more available for discussion, and to point out the deficiencies in our knowledge. If it stimulates investigation; if it leads others to the examination of the greater Asiatic, African, South American and Australian rivers, or to more extended studies of the chemistry of rainfall, its main purpose will be fulfilled. The assumptions which it is now necessary to make ought to be replaced by definite evidence of a sort which is easily obtainable.[1]

[1] Published by permission of the Director of the United States Geological Survey. Becker's memoir, to which references have been made, appears simultaneously with this paper.

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 56, NUMBER 6

THE AGE OF THE EARTH

BY
GEORGE F. BECKER

(PUBLICATION 1936)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
JUNE, 1910

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

THE AGE OF THE EARTH

By GEORGE F. BECKER

CONTENTS

PAGE

Introductory Review 1

Age from Sodium Accumulation 6
The data 6
Increment of oceanic sodium 6
Results of asymptotic accumulation 11

Age from Refrigeration 17
Historical note 17
Modified problem 19
Numerical results 24

Conclusions 27

INTRODUCTORY REVIEW

The birthday of the world known to us is commonly regarded as coinciding with the epoch of Leibnitz's *consistentior status*.[1] This great philosopher believed that the earth solidified from a state of fusion by stages similar to those he had observed in the refrigeration of large masses of metal: cavities analogous to blow-holes developed and burst; thin partial crusts formed and broke; in some cases such crusts were extensive enough and sufficiently cool to receive bodies of water, but were not strong enough to support the accumulated liquid and presently gave way, so that fresh convulsions ensued. At length, through the progress of refrigeration, the globe emerged into "a state of greater consistency." Then chaos was at an end and permanent oceans became possible.

It is interesting to note that Leibnitz seems to have had in mind not merely dry fusion, but fusion with the co-operation of water, or what would now be called aqueoigneous fusion.

Three methods have been devised for ascertaining the age of the ocean: one from the accumulation of stratified rocks; another from chemical denudation; and the third from the progress of refrigeration. Closely allied to these is Sir George Darwin's discussion of the lapse of time since the earth and the moon parted company.[2]

[1] Protogaea, 1749. A sketch of this posthumous work appeared in the Acta Eruditorum, Jan., 1693.

[2] Phil. Trans., London, vol. 170, 1879, p. 511; and vol. 171, 1880, p. 882.

A faultless mode of arriving at the ocean's age is perhaps unattainable, though better ways than are now available may possibly be elaborated hereafter. All that can be hoped for at present is that diverse methods may lead to estimates of the same order of magnitude; and such a result is more important just now than ever before. By physical reasoning geologists have been compelled to adopt a moderate estimate of geological time. Of late, however, physicists engaged in studies of radioactivity have reached the conclusion that certain uranium minerals are of an enormous age, which is estimated by simple though tremendous extrapolation. If geologists can now give convincing reasons for adhering to ages within a hundred million years, or even within two hundred, they may partly repay the heavy debt due by them to Kelvin and his intellectual heirs.

So long ago as 1860 John Phillips,[1] the originator of the mechanical theory of slaty cleavage, estimated that the time required for the deposition of the stratified rocks lay between 38 and 96 million years. So far as my reading goes, this was the only reasonable estimate prior to Kelvin's truly epoch-making paper of 1862.[2] During the last 20 years much energy has been expended upon the study of the maximum thickness of strata and the time-rate of their deposition. In 1890 de Lapparent thus estimated a period of from 67 to 90 millions of years.[3] The most careful investigation of this kind yet made is due to Mr. Charles D. Walcott who, in 1893, carried out minute and cautious studies of the rate of deposition and of the amount of accumulation, both mechanical and chemical.[4] His estimate for the lapse of time since the base of the Cambrian is 27,640,000 years and he allows for the Algonkian a period of 17,500,000 years. As a matter of course this last figure rests on extremely imperfect data and should probably be increased. Mr. Walcott considered 70 millions the maximum age. In 1899 Sir Archibald Geikie stated that, so far as he was able to form an opinion, 100 million years would suffice for the formation of the stratified rocks,[5] and in 1900 Mr. W. J. Sollas, assuming a constant rate of deposition, reached an age of 26½ million years.[6] In 1909 Mr. Sollas increased this estimate to nearly 34 million years,[7] but in view of erosions and the uncertainties involved he inclines to believe, as do many others, that the pre-Cambrian sediments took as much time for their deposition as those from the base of the Cambrian to the top of the column. Making also an allowance for gaps, he thinks the stratigraphical column, if complete, might indicate 80 million years. He draws especial

[1] "Life on the Earth," etc., 1860, p. 119.
[2] Trans. Roy. Soc. Edinburgh and Thomson and Tait, Nat. Phil., Pt. II, p. 468.
[3] Bull. Soc. Géol. de France, vol. 18, 1890, p. 351.
[4] Journal of Geol., vol. 1, 1893, p. 675.
[5] Brit. Assoc. Adv. Sci., 1899, p. 727.
[6] Brit. Assoc. Adv. Sci., 1900, p. 711.
[7] Mr. Sollas assumes a constant rate of deposition of one foot per century and thinks most geologists would incline to a higher rate. Quart. Jour. Geol. Soc. London, vol. 65, 1900, p. CXII.

attention to the discrepancy between stratigraphical estimates and those from sodium accumulation in the ocean. If Mr. Walcott's estimate for time since the base of the Cambrian be doubled, in accordance with the opinions stated above, it gives 55 million years.

The introduction into modern geology of estimates founded on chemical denudation is due to T. Mellard Reade,[1] but Mr. J. Joly was the first to show that sodium is the only element which can be trusted to afford good estimates of the lapse of time involved in denudation. Adopting the hypothesis that the sodium content of the ocean is derived at a constant rate from that of the rocks, Mr. Joly, in 1899, arrived at an age of between 80 and 90 million years, and this he increased by 10 million in 1900.[2] In 1909 Mr. Sollas made a very searching inquiry into this subject, availing himself of much material published since Mr. Joly's papers, and, on the same hypothesis of uniformity, placed the age of the ocean between 80 million and 150 million years.[3]

Very curiously, the great astronomer Edmund Halley nearly 200 years ago devised a method of determining the age of the ocean from the amount of salt which it contains.[4] He recognized that the means he proposed for determining the annual increment of salt were impracticable and, writing long before Lavoisier was born, could not have guessed that analysis of river waters would become a simple matter. It is not strange that Halley's paper was completely forgotten, but it is now of such interest and is so inaccessible to a majority of geologists that an extract from it will not be regarded as out of place here.

A short Account of the Cause of the Saltness of the Ocean, and of the several Lakes that emit no Rivers; with a Proposal, by help thereof, to discover the Age of the World.

There have been many attempts made and proposals offered, to ascertain from the appearances of nature, what may have been the antiquity of this globe of earth; on which, by the evidence of sacred writ, mankind has dwelt about 6000 years; or according to the Septuagint above 7000. . . . . This inquiry seeming to me well to deserve consideration, and worthy the thoughts of the Royal Society, I shall take leave to propose an expedient for determining the age of the world by a medium, as I take it, wholly new, and which in my opinion seems to promise success, though the event can not be judged of till after a long period of time; submitting the same to their better judgment. What suggested this notion was an observation I had made, that all the lakes in the world, properly so called, are found to be salt, some more some less than the ocean sea, which in the present case may also be esteemed a lake; since by that term I mean such standing waters as perpetually receive rivers running into them, and have no exit or evacuation. . . . .

---

[1] Proc. Liverpool Geol. Soc., vol. 3, 1876, p. 211.
[2] Trans. Roy. Soc. Dublin, vol. 7, 1899, p. 23; and Brit. Assoc. Adv. Sci., 1900, p. 339.
[3] Quart. Jour. Geol. Soc. London, vol. 65, 1909, p. CXII.
[4] Phil. Trans., vol. 29, 1715, p. 296. See also Science, vol. 31, 1910, p. 459.

Now I conceive that as all these lakes do receive rivers and have no exit discharge, so it will be necessary that their waters rise and cover the lan until such time as their surfaces are sufficiently extended, so as to exhale vapor that water that is poured in by the rivers; and consequently that lake must be bigger or lesser, according to the quantity of the fresh they receive. But the vapors thus exhaled are perfectly fresh; so that the saline particles that are brought in by the rivers remain behind, while the fresh evaporates; and hence it is evident that the salt in the lakes will be continually augmented, and the water grow salter and salter. . . . .

Now if this be the true reason of the saltness of these lakes, it is not improbable but that the ocean itself is become salt from the same cause, and we are thereby furnished with an argument for estimating the duration of all things, from an observation of the increment of saltness in their waters. For if it be observed what quantity of salt is at present contained in a certain weight of the water of the Caspian Sea, for example, taken at a certain place, in the driest weather; and after some centuries of years the same weight of water, taken in the same place and under the same circumstances, be found to contain a sensibly greater quantity of salt than at the time of the first experiment, we may by the rule of proportion, take an estimate of the whole time wherein the water would acquire the degree of saltness we at present find in it.

And this argument would be the more conclusive, if by a like experiment a similar increase in the saltness of the ocean should be observed: for that, after the same manner as aforesaid, receives innumerable rivers, all which deposit their saline particles therein; and are again supplied, as I have elsewhere shewn, by the vapors of the ocean, which rise therefrom in atoms of pure water, without the least admixture of salt. But the rivers in their long passage over the earth do imbibe some of the saline particles thereof, though in so small a quantity as not to be perceived, unless in these their depositories after a long tract of time. And if upon repeating the experiment, after another equal number of ages, it shall be found that the saltness is further increased with the same increment as before, then what is now proposed as hypothetical would appear little less than demonstrative. But since this argument can be of no use to ourselves it requiring very great intervals of time to come to our conclusion, it were to be wished that the ancient Greek and Latin authors had delivered down to us the degree of the saltness of the sea, as it was about 2000 years ago; for then it can not be doubted but that the difference between what is now found and what then was, would become very sensible. I recommend it therefore to the Society, as opportunity shall offer, to procure the experiments to be made of the present degree of saltness of the ocean, and of as many of these lakes as can be come at, that they may stand upon record for the benefit of future ages.

If it be objected that the water of the ocean, and perhaps of some of these lakes, might at the first beginning of things, in some measure contain salt, so as to disturb the proportionality of the increase of saltness in them, I will not dispute it: but shall observe that such a supposition would by so much contract the age of the world, within the date to be derived from the foregoing argument, which is chiefly intended to refute the ancient notion, some have of late entertained, of the eternity of all things; though perhaps by it the world may be found much older than many have hitherto imagined.

Ever since the publication of Mr. Joly's papers Mr. F. W. Clarke and I ve been deeply interested in his method and in chemical denudation. A

portion of the large mass of data accumulated during the past decade has been determined at our suggestion, though most of the hydrological work of the U. S. Geological Survey, including the very numerous analyses executed under the charge of Mr. R. B. Dole, has formed part of a systematic effort to develop the mineral resources of the Commonwealth. In pursuance of our common aim Mr. Clarke has now completed a review of all available data, not only for the United States but for the world, and his paper is published by the Smithsonian Institution under the title, "A Preliminary Study of Chemical Denudation."[1] His results form the basis of a discussion of the age of the ocean which will be presented below.

Kelvin in 1862 first discussed the age of the earth considered as a cooling body. His results were for some years received with sorrow and indignation by most geologists and especially by evolutionists, who then desired unlimited time in which to effect the development of species. More mature study has convinced the scientific world that there is no necessary discrepancy between Kelvin's 20 to 400 million years, with a probable 98 million, and the conclusions of geologists or paleontologists. In 1893 Clarence King, with the aid of Mr. Carl Barus, introduced the important criterion of tidal stability and reached the conclusion that 24 million years best represented the conditions.[2] This result was accepted by Kelvin in 1897[3] and he then placed the limits at 20 and 40 million years. The earths considered had uniform initial temperatures. In 1908 I showed that such a distribution of temperature necessarily involved a prolonged period of tidal instability and discussed a globe the initial temperature of the outer shell of which increased in simple proportion to the distance from the surface.[4]

Only Sir George H. Darwin has discussed the age of the earth from a purely astronomical point of view. From his theory of the earth-moon system he derived an estimate of more than 56 million years which for a long time stood rather alone between groups of higher and lower figures.

In the succeeding pages will be found my discussion of Mr. Clarke's data and also a revised edition of my paper on the age of the earth as determined from refrigeration. The two arguments accord remarkably well.

---

[1] Smithsonian Miscellaneous Collections, vol. 56, No. 5, 1910.
[2] Amer. Jour. Sci., vol. 45, 1893, p. 1.
[3] Trans. Victoria Inst., vol. 31, 1899, p. 11.
[4] Science, vol. 27, 1908, p. 227.

AGE FROM SODIUM ACCUMULATION

The Data

For comparison with the results of radioactive studies age determinations from chemical denudation have an advantage over those from refrigeration, because decomposition of the rocks is only remotely affected by thermal action and radioactivity. Mr. Joly's method of finding the age of the ocean consists substantially in dividing the total sodium content of the ocean by the amount of sodium annually poured into it by the the rivers. The result is corrected for wind-borne sodium and marine denudation. I cannot agree that this quotient is the required age, but before discussing that matter it is essential to ascertain as nearly as possible the numerator and the denominator of Mr. Joly's ratio.

Mr. Clarke's new discussion has already been referred to and he has been kind enough to furnish me with the following data. The total sodium content of the ocean is $14{,}130 \times 10^{12}$ metric tons. The annual uncorrected sodium increment escaping from the rivers is 175×10^6 tons. The river-borne unchloridized sodium is 62.57×10^6 tons. The amount of average igneous rock needed to supply the total sodium of the ocean is 48.225×10^6 cubic miles, while the amount of rock necessary to supply both this and the sodium retained as silicates (mostly feldspars) in the sedimentaries would occupy 77.570×10^6 cubic miles. This would make a shell 2,050 feet thick enveloping the globe. These figures I shall accept.

The Sodium Increment.

To the order of accuracy required for the purposes of this paper there is little difficulty in finding a correction for wind-borne sodium. The normal distribution of chlorine throughout New England and New York has been studied in considerable detail and the results are stated in Mr. Daniel D. Jackson's paper on this subject.[1] Nearly all of the normal chlorine of this region is due to wind-borne sea-salt and I find by examination of typical cross-sections of the chlorine charts that the total chlorine is fairly represented by supposing the coastal value of six parts per million to be constant for 20 miles inland and there to vanish.[2] The waters examined for normal chlorine were by preference surface waters, and since the region has a rainfall of 45 inches with no excessive evaporation, it seemed probable that if the rain from appropriate rain gauges had been bottled periodically, the collected precipitation would show substantially

[1] Jackson, D. D., The normal distribution of chlorine in the natural waters of New York and New England: Water-Supply Paper U. S. Geol. Survey, No. 144, 1905.

[2] The means employed was to plot a typical cross-section, adapt to the observed points a logarithmic curve, and take its area from the shore to a distance theoretically infinite. The section selected as representative passed through Rye, N. H., and bore N. 65 W. The method is capable of much elaboration.

the normal chlorine. Inquiry of Mrs. Ellen S. Richards as to the chlorine of the rainfall in Massachusetts confirmed this view. The assumed relation leads at once to the amount of wind-borne sodium along a length of coast of about 500 miles; and supposing the total length of the coast of the United States (without counting indentations) to be 4,500 miles, the order of magnitude of the correction required is 6 per cent. Mr. Clarke from different data and by a different course of reasoning estimates this correction at 7 per cent.

Applying a 6 per cent. correction reduces the annual river-borne sodium of the world an eighty-six millionth part of the oceanic sodium, or to 164.5×10^6 tons, of which more than half is combined with chlorine.

The origin of oceanic chlorine has long been regarded as mysterious. Average rock contains less than 2 per cent. of the chlorine needed to convert the accompanying sodium into chloride, and this has led to hypotheses of a primitive atmosphere heavily charged with chlorine or to an original solid surface containing great quantities of ferrous chloride. It may still be needful to seek such explanations, yet they seem to me highly unsatisfactory. From the base of the Cambrian onward some animal forms, such as Lingula, have persisted practically without change, and there is every paleontological indication that Paleozoic sea-water was a medium substantially like that of to-day. Had the sea been overcharged with chlorine in any form, consequences of this fact would almost certainly have manifested themselves in the composition of sediments and the decomposition of rocks, but nothing known to me indicates any unfamiliar chemical conditions. In the absence of such proofs it seems unreasonable to assume a Cambrian ocean essentially different from that of to-day. Now the ordinary geological estimate of the age of Cambrian strata is something like 30 million years; and during that period some 30 million times 63 million tons of unchloridized sodium, or perhaps considerably more than this, has been poured into the sea. All of this sodium has found chlorine to saturate it, once and a half its own weight of chlorine. Where can all this have come from?

We all know definitely that volcanoes and solfataras emit free chlorine, chlorhydric acid, ammonium chloride, calcium chloride and sodium chloride. Hot springs and certain cold springs also emit some of these, especially calcium chloride. So abundant is chlorhydric acid in the emanations of Vesuvius that according to Mr. Suess [1] vegetation has been blasted over large areas by acid rain, and according to Mr. Stoklasa [2] the greater part of the "pine-tree" clouds above the crater of Vesuvius during eruptions consists of chlorides, mainly ammonium chloride. Other volcanoes send out similar emanations and since there are hundreds of

[1] Ueber heisse Quellen: Verhandl. Gesell. deutsch. Naturf. und Aerzte, 1902, p. 113.
[2] Ber. Deutsch. chem. Gesell., vol. 39, 1906, p. 3530.

volcanoes and thousands of solfataras the total output must be very large. Cold chloride springs are not uncommon and are widely distributed at points far distant from volcanic centers.

Thus the question arises whether it is absurd to suppose that the chlorine product of volcanoes and solfataras is sufficient to saturate the unchloridized river sodium. It may be fanciful to subject such an hypothesis to computation, but this seems to me the only way to judge whether or not an absurdity is involved. Suppose then that all the chlorine were emitted as chlorhydric acid. The unchloridized river sodium being taken at 62.57×10^6 metric tons each year would require very nearly 100×10^6 tons chlorhydric acid. If this amount of gas were to issue from a single vent, at a temperature of 200° and a corresponding pressure of 6.62 kilograms per square centimeter into atmosphere at 0°, the opening would emit 29×10^6 metric tons per square meter per annum.[1] Thus the area of the vent required would be 100/29 or less than 3½ square meters, so that (neglecting friction) 1000 vents each of 6½ cm. diameter working continuously would emit it all.[2] Considering the many violent eruptions of volcanoes and the large number of solfataras, a chlorhydric acid production of 100 million tons does not seem at all impossible. If the entire amount were uniformly distributed over the globe and reached the surface in a rainfall of one meter, this precipitation would contain less than a fifth of a millionth part of chlorine. Such an amount of chlorine would be recorded by hydrologists as "a trace."

Since the only known sources of chlorine are volcanoes and juvenile waters and these sources of supply are not manifestly insufficient, I consider it fair to conclude that the juvenile chlorine is and has been since the Cambrian about equivalent to the sodium set free from the rocks. Doubtless there have been variations in the relations between these two elements which were considerable from the point of view of the hydrologist, but they were, apparently, not great enough to unfit the ocean for the abode of a salt water fauna,[3] or to characterize its geochemical behavior.

What the conditions were which prevailed before the Cambrian is naturally more uncertain, but I do not believe that a primitive acid ocean should be invoked until probable explanations involving juvenile chlorine have been exhausted. If the earth is an aggregate of meteorites, many of them siderolites, charged, as Mr. Clarke has suggested, with lawrencite, it seems to me natural to suppose that most of this chloride, whose density is nearly 3, would be deeply buried beneath the lighter

[1] Cf. Ch. Briot, Théorie Méc. de la Chaleur, 2d ed., 1883, Section 113.

[2] The present pig-iron production is about 60 million long tons and the weight of air which must be blown into the blast furnaces producing this amount of pig is about 320 million long tons.

[3] Possibly fluctuations in the composition of sea-water may have affected the rate of evolution of organisms or limited their survival.

siliceous rocks. Its gradual decomposition might yield chlorine, and no other equally probable origin for the chlorine of volcanoes or deep springs is known.

Assuming that the supply of juvenile chlorine not combined with sodium is sufficient to maintain the present ratio of chlorine to bases in the ocean, it is possible to account for a part of the river-borne sodium chloride. Of the volcanic chlorine substantially 3/4 must fall into the sea and if this were exactly equivalent to the unchloridized river sodium, the volcanic chlorine precipitated on the continental areas would suffice to chloridize one-third as much sodium as escapes chloridation until it reaches the ocean. Furthermore, in the present ocean there is about one and a seventh times as much chlorine as is needed to combine with oceanic sodium. On the hypothesis suggested this should also be the case on land. Thus if the unchloridized river sodium is 62.57×10^6 tons, the volcanic chlorine should be equivalent to the following amount of sodium:

$$\frac{8}{7} \times \frac{4}{3} \times 62.57 \times 10^6 = 95 \times 10^6 \text{ tons}$$

The chlorine equivalent of this sodium equally distributed over the earth's surface and dissolved in a rainfall of R meters would give a normal chlorine content

$$C = \frac{0.2864}{10^6 R}$$

so that if the rainfall were one meter, the normal chlorine content at inland stations would be less than 3/10 of one part per million. It is to be desired that analyses of the rainfall should be made at a well distributed set of stations for many purposes, one of them being to ascertain what is the normal chlorine of the rainfall. This, however, may vary from year to year.

The total river-borne sodium less 6 per cent. for cyclic sodium is 161.5×10^6 tons. About 2 per cent. of this amount is covered by the chlorine of the rocks and, according to the hypothesis of volcanic chlorine set forth above, 95×10^6 tons more is thus accounted for. The sum of the two items amounts to over 98×10^6 tons, but leaves no less than 66×10^6 tons of river-borne sodium, or 40 per cent. of the total, which is chloridized but the chlorine of which has not yet been traced.

There is no doubt that a part of this sodium chloride is juvenile and that another portion is what may be called *secular*. Sediments at their first emergence from the ocean are saturated with salt water and any porous rocks, particularly sandstones, if temporarily submerged are recharged with salt water. Well compacted sands contain approximately 20 per cent. of interstitial space, and it is easy to compute that the whole mass of sandstones must originally have contained highly important

quantities of sodium chloride. On the other hand, a large part of the strata have been exposed to the leaching of vadose waters for so many million years that it is difficult to imagine how they can still retain any secular salt. The subject of juvenile sodium chloride is perhaps even more obscure. That many volcanic springs and many springs originating far below the stratified rocks bring ready-made sodium chloride to the surface is certain. Even where there are now no springs of this description, there may have been such at comparatively recent geological dates.

That sedimentary rocks do actually carry large quantities of disseminated salt seems to me fully established by the recent work of the hydrologists, in particular that of Mr. Dole. They have left no doubt that waters flowing through stratified rocks carry far more chlorine than those from massive drainage basins, and it is beyond question that this excess of chlorine is combined with alkalis. I have only very lately learned to appreciate the facts, and have previously erred in supposing the disseminated salt of the sedimentaries unimportant.

There seems to me the best reason to suppose that the origin of disseminated salt in strata is open to investigation. Careful chemical work on sufficiently numerous specimens should show whether the compounds associated with the salt are those to be expected from sea-water or those characteristic of deep springs, and at least a rough estimate of the proportion of secular sea-salt should be attainable.

At present I see but one way in which to form any opinion as to the division of the questionable 66×10^6 tons of sodium into secular and juvenile portions. Mr. Clarke has shown that a shell of average igneous rock enveloping the globe and 2050 feet thick would yield all the sodium of the ocean and the unchloridized sodium of the sedimentaries, and this result is confirmed by computation from the magnesium contents. If the continental area has always been as large as now, Clarke's shell would make a continental layer four times as thick, or 8200 feet. Thus if there were no juvenile sodium the total denudation of massive rocks, since the waters under the heaven were first gathered together unto one place and dry land appeared, would slightly exceed a mile and a half. Considering the vast well-demonstrated erosions, this figure is by no means startling. If the whole 66×10^6 tons were juvenile, the layer would reduce to 60 per cent. of 8200 feet, or to 9/10 of a mile, a depth considerably smaller than that of the deepest part of the Grand Cañon of the Colorado. As a field geologist I should unhesitatingly reject any train of reasoning however plausible which led to so low an estimate as this of the total denudation. Some juvenile sodium there certainly is, but it seems to me that this must form but a small part of the 66×10^6 tons.

To be on the safe side I shall estimate the age of the ocean on two

hypotheses each of which seems extreme, first that all of the questionable amount of sodium is secular and second that two-thirds of it are juvenile.

Before proceeding to these estimates, however, it is necessary to consider other uncertainties. At the present day the continent of North America stands above its average level, and this state of things appears to prevail in the other continents as well. The effect is to increase the potential of the streams and to hasten erosion. Again, the last glacial period is recent; and the ice has laid bare great areas of feldspathic rocks, which are thus more open to weathering than they were during the Tertiary. For this reason the yield of sodium per unit area must be above the mean for drainage basins including glaciated areas. Corrections for these conditions would tend to increase estimates of the earth's age. Finally, marine erosion needs consideration. The abrasive effect of the waves and tides on rock fragments and pebbles between high and low water marks is intense and world-wide, but the average width of beach is very small, much smaller than it would be were the continents to subside even a couple of hundred feet, and smaller than the mean width for the ocean's history. The sodium extracted by the waves is not represented in the figures for the rivers and a correction for marine erosion would tend to decrease estimates of the earth's age, or to offset the corrections for glaciation and high level. It is to be hoped that means may be found of evaluating the algebraic sum of these corrections, but I know of none; I cannot even guess its sign and must assume it to be zero.

Supposing none of the river-borne sodium to be juvenile the annual sodium increment is 98×10^6 tons and the ratio of the total oceanic sodium to this increment is 144.2×10^6. This number of years would be the corresponding age of the ocean if Mr. Joly's method of estimation were adopted. Strictly speaking, the age should be somewhat greater, because the whole of the secular sodium still remaining in the rocks ought to be credited to the total oceanic sodium; but it is difficult to imagine that this could have any substantial influence on so huge a total as 14×10^{15} tons. On the second hypothesis, that 44×10^6 tons of sodium are juvenile, the increment would be 142×10^6 tons and the ratio 99.5×10^6 provided that no allowance is made for juvenile additions to the oceanic sodium by submarine springs. Any such additions would be equivalent to primitive salinity of the ocean and imply a further reduction in age.

Results of Asymptotic Accumulation

To find the age of the ocean from the total oceanic sodium and its annual increment, it is manifestly indispensable to know or to assume a definite time relation between them. Mr. Joly's hypothesis is that the total sodium of the ocean is the annual increment of sodium multiplied by the age of the ocean in years; but another relation not less simple

seems to me much more probable and better fitted to give a first approximation to the truth.[1]

Oceanic sodium is at least chiefly derived from lime-soda feldspars which as essential constituents are practically confined to Archean and later igneous rocks. The original surface of the earth must have consisted of such rocks to the exclusion of all others, while at the present day the greater part of the land area is covered with sedimentaries. Now the rate of decomposition of rocks is chiefly dependent on exposure. Even in areas of ancient feldspathic massives decomposition does not seem to penetrate to great depths. Thus in the southern Appalachians great areas of gneiss and allied rocks are now covered with a blanket of saprolite (rotten rock in place) which is in many localities 50 feet in thickness, but at all the points where I have observed it, less than 100 feet thick. Immediately below the saprolite blanket there is incipient decomposition and the feldspars are milky, but not many yards lower down the feldspars are characteristically translucent and the rock bluish in tint. A layer of decomposition products 100 feet thick seems to arrest decay. Corresponding statements are true of tertiary volcanics, excepting where the decomposition is solfataric. On the other hand mesozoic and paleozoic massive rocks deeply buried under sediments are in many cases found to be very free from decomposition. In short, buried massives decompose at a rate which is scarcely sensible.

It is quite imaginable that in the far distant future all the massive rocks might be thoroughly decomposed down to sea level or a trifle below. The continents would then be exclusively detrital. Under such conditions there could be no further important additions to the sodium content of the ocean, for there would then be no leaching; while mere diffusion to any considerable distance is too inordinately slow to produce any noteworthy result even in millions of years.

Thus in the distant past there must have been a time when a far greater mass of massive rock was decomposed each year than now decays in the same period; and a limit to this process can also be foreseen. The total area of exposed massives has surely diminished and will continue to diminish. Climate and temperature may perhaps have been in the past much what they are to-day; the rate of chemical denudation per unit area may not have changed considerably, but the most rigid uniformitarian would not maintain that the total area of exposed massive rocks has been constant. The inference seems unavoidable that sodium accumulation is an asymptotic process which progressed more rapidly (though possibly not with greater intensity) in the distant past and will come substantially to an end when a certain very finite layer of surface material has been ex-

[1] Vide Science, vol. 31, 1910, p. 509.

hausted. It seems worth while to attempt some estimates based on this conception of the saltness of the ocean.

There is a great deal of evidence for the elder Dana's generalization as to the permanence of continental areas, and it is accepted by most physical geologists. Assuming its truth it should be possible to arrive at a mean value for the exposed land surface throughout geological time, and this would be a constant of the same order of magnitude as the present continental area.

The simplest law compatible with the conditions set forth is that, at any given time, the decrease per unit of time in the area of the sodium-producing exposures has been simply proportional to the temporary area of the exposures. This is equivalent to the hypothesis that the area of the feldspathic rocks can be represented approximately by the descending exponential; for if y is the exposed area at a given time, t, and c a constant, the decrease is represented by

$$dy/dt = -y/c, \text{ whence } y = Ae^{-t/c}$$

Here A is the extent of the exposure when $t = 0$, or when erosion is supposed to begin. On the strength of Dana's law A may be taken as the mean land area of the globe.

Suppose the total sodium content of the ocean at time t to be N, and let m be the annual yield of sodium per unit area, so that my is the increment of N in one year from time t. Then, m being constant,

$$N = \int_0^t my\,dt = Amc\,(1 - y/A)$$

or

$$c = \frac{N/my}{A/y - 1}$$

while the formula for the age of the ocean is

$$t = c\ \log_e \frac{A}{y}$$

This hypothesis takes no account of a primitive saline ocean, though that condition could be included by merely adding another constant. When t becomes infinite, y reduces to zero and, therefore, the limiting value of N is Amc.

The selection of the exponential to represent the phenomena under discussion is neither a random one nor dictated by mere convenience. This function is well known to play a leading part in the theory of those natural operations which may be classed generically as processes of absorption or gradual extinction,[1] just as it also expresses the gradual accumulation of money at compound interest. The descending exponential ex-

[1] Cf. Cournot, Théorie des fonctions et du calcul infinitésimal, vol. 1, chap. 2.

presses the decay of velocity of a body moving in a resisting medium; or the gradual extinction of light in an absorbing medium; the loss of electricity or of heat by radiation from a conductor; the decay of radioactivity, and an endless number of similar phenomena. Whenever the loss of an entity during any instant is simply proportional to the amount of the entity then present, the process must be expressed by the exponential.

It does not follow that the decomposition of feldspathic rocks is accurately represented by a single exponential term. Were the whole history of these rocks known it might very probably appear that the process is complex and should be expressed in some such manner as

$$y = Ae^{-t/e} + A_1 e^{-t/e_1} + \ldots .$$

one term expressing, for example, the decay of albite; another that of anorthite, etc.

There is no close analogy between the asymptotic diminution of the area of those feldspathic rocks which are subject to erosion and the process of refrigeration of a globe or that of the diffusion of solutions, although these also are asymptotic. In the diffusion of solutions the molecular flow across a plane during an instant of time is proportional to the difference of concentration of the two thin layers divided by the plane. If one of them is devoid of solute, the process commences at immense speed; but it soon becomes very slow because the layers tend to acquire the same concentration.[1] Beneath areas in which there is no erosion, such as the ocean floor or lake bottoms, decomposition by diffusion is probably in progress; but the amount of sodium thus contributed to the rivers or the sea must be negligible in comparison with that yielded by denudation.[2]

At present it appears useless to speculate on sodium accumulation as represented by a series of exponential terms, nor can I think it needful. Precisely as a cubic mile of granite may be regarded as isotropic because the mass is so large compared with that of the single æolotropic grains of which it is composed, so local inequalities of chemical denudation disappear in the average of innumerable diversities. There must be some descending exponential which will fairly represent the process and the problem reduces to making a judicious selection of constants.

The earlier portion of this paper is devoted to a discussion of the value of N/my, or the ratio expressing the earth's age on Mr. Joly's hypothesis, and limiting values have been found for it. To compute the age on the exponential hypothesis it only remains to find a value of y/A for the present time. From Mr. Charles Schuchert's valuable memoir on paleo-

[1] For examples of the extreme slowness of diffusion see Amer. Jour. Sci., vol. 3, 1897, p. 27. For definition of the process, see Everett's c. g. s. system of units, 1902, p. 151.

[2] Although the hyperbola is an asymptotic curve, its equation would not express the course of the extraction of sodium from the outer shell of massive rocks, for that would imply that this shell would in time yield an infinite quantity of the metal.

geography[1] it appears that the mean area of the continent of North America has been about 8/10 of its present area. While the paleogeography of no other continent seems to have been so satisfactorily treated, it is generally acknowledged that the continents have grown more stable and the ocean deeper. So far as existing continents are concerned, therefore, it is fair to conclude that the mean land exposure has been somewhat less than the actual land area. Many paleontologists, however, think themselves driven by zoölogical reasoning to believe in the former existence of extensive continents bridging the great oceanic basins of the present day. This seems to me mechanically improbable and some great authorities such as Sir Archibald Geikie[2] refuse to concede the point. If the existence of such sunken continents of unknown extent were to be assumed, there would be no such thing as approximating to a mean land area. All I can do, therefore, is to point out that the effect of such bodies of land would be greatly to reduce the appropriate estimate of the earth's age by the method under discussion.

Assuming the permanence of continental areas, the uncertainty of the mean area is partially offset by marine denudation; for when shallow seas invaded the continents, breakers and the tidal wave must have triturated far more rock than is ground up on the shores of present continents.

A careful study of the areas of exposure of the principal geological formations was made by the late distinguished physical geographer, Lieutenant-General Alexis von Tillo. This includes the Archean and the younger eruptives, the results being expressed in hundredths of the total surveyed area. The following is an extract from von Tillo's table:[3]

Continent.	*Archean.*	*Eruptives.*	*Total.*
Europe	20.6	1.3	21.9
Asia	17.7	4.7	22.4
Africa	18.4	2.2	20.6
Oceanica	20.0	4.8	24.8
North America	27.2	5.5	32.7
South America	18.7	4.6	23.3
Mean	20.3	4.0	24.3

The most recent geological map of North America (compiled by Mr. Bailey Willis) shows that the relative area of exposed feldspathic rocks on this continent is not so large as was supposed when von Tillo wrote, and, though I have made no minute measurements, this exposure as now mapped seems not to exceed 25 per cent. With this emendation, von Tillo's table shows a truly remarkable uniformity throughout the world, all the figures lying between a fourth and fifth of the total area, the average

[1] Bull. Geol. Soc. Am., vol. 20, 1910, p. 427.
[2] Text-book of Geology, 4th ed., 1903, p. 1365.
[3] Comptes Rendus, Paris, vol. 114, 1892, pp. 246, 967.

being 23 per cent. He too was impressed by the smallness of the variation in the relative areas of Archean exposures.

If the present continental area were the mean land area von Tillo's data would give at once $y/A = 0.23$, but since the land now stands at a high level the true value of A is smaller than the actual area and the quantity 0.23 must be modified accordingly.

The greater part of the area of massive rocks lies at a considerable distance from the sea, so that a partial submergence would diminish the continental area much more in proportion than the exposure of feldspathic rocks. In order to include, if possible, the true mean value of the land area, I shall take y/A first at three-tenths and again at one-fourth; the latter exceeding the 0.23 derived from von Tillo's data by a proportion relatively trifling while, closely enough, $0.3 = 0.23/0.8$, the denominator representing the mean taken from Mr. Schuchert's memoir.

With these data the results are as follows:

y/A	0.30	0.30	0.25	0.25
$N\ 10^{-6}/my$	144.2	99.5	144.2	99.5
$c/10^6$	61.80	42.64	48.07	33.17
Amc	$10N/7$	$10N/7$	$4N/3$	$4N/3$
$t/10^6$	74.4	51.3	66.6	46.0

Here the second line gives the ages on Mr. Joly's hypothesis in millions of years, and the last that computed from the logarithmic relation. The fourth line gives the ultimate amount of oceanic sodium calculable from the equations, and inferentially the thickness which Clarke's shell may reach, 10/7 or 4/3 of its present value. With the larger fraction this shell, now measuring 2050 feet, would ultimately attain a thickness of 2930 feet, or if it were all piled onto our continents, 2.2 miles. The difference between this estimate of the ultimate size of Clarke's shell and its present dimensions represents a volume 2½ times as great as that of the present continents above sea level. Such, then, on this rather extreme assumption, would be the volume of massive rock, still fresh, but doomed to eventual decomposition. Thus the hypothesis leaves an ample margin for future igneous effusions and epeirogenic uplifts without putting an excessive strain upon the imagination.

Of the ages computed, the greatest, 74 million years, is the most valuable. It is indisputable that the process of rock decomposition is an asymptotic one and at least roughly represented by the simple exponential, while every effort has been made to select for the first computation the highest reasonable values for N/my and y/A. All the estimates would be greatly reduced if a primitive salinity of the sea or the former existence of land areas in the great oceanic basins were assumed. Those who do not feel obliged to accept either of these hypotheses may perhaps agree in my

opinion that the age indicated is between 70 and 50 million, probably closer to the upper limit than to the lower one.

The extreme values of Mr. Joly's ratio, N/my, which I am led to adopt, do not differ greatly from those preferred by Mr. Sollas, viz., 80 million and 150 million, while the ages computed from the logarithmic expression fall in very well with Mr. Sollas's results from stratigraphic reasoning. Again, if Mr. Walcott's estimate is amended by making the age of the earth twice as great as the lapse of time since the beginning of the Cambrian, the resulting 55 million years accord with the result here reached. Stratigraphy and sodium denudation as here discussed thus give results which are at any rate of the same order of magnitude.

AGE FROM REFRIGERATION

Historical Note

Kelvin's famous and epoch-making paper on the secular cooling of the earth was published in 1862.[1] His problem was to find the time which would elapse before a globe completely solid from center to surface and having throughout a certain uniform initial temperature would cool so far as to reduce the surface gradient of temperature to any given value. He assumed an initial temperature of 3900° C., a diffusivity of 0.01178 in c. g. s. units and a final surface gradient of 1° C. in 27.76 m. or 1° F. in 50.6 feet. These data discussed by one of Fourier's theorems give for the age of the earth 98×10^6 years. Kelvin, however, expressly directed attention to the fact that the effect of temperature in modifying diffusivities is almost unknown, and that the original distribution of temperature is uncertain. He also referred to the great differences in the surface gradient of temperature, which varies with the locality, as he stated, from 1° F. in 15 feet to 1° F. in 110 feet. He, therefore, allowed very wide limits in his estimate and placed the age between 20 million and 400 million years.

In 1893 Clarence King made a very important contribution to the subject[2] by introducing the criterion of tidal stability. Mr. Barus determined for him the melting point of diabase in terms of depth. If in any hypothetical earth consisting solely of diabase the temperature in any couche were to exceed the melting point of diabase, then tidal instability would set in, the crust would break down and chaos would reign for the time being. In a real earth the same result would follow provided the couche were in a region where diabase or equally fusible rocks are to be expected. Excluding such cases, King found that the age of the earth could not exceed 24 million years when Kelvin's values for diffusivity and

[1] Trans. R. S. Edinburgh, reprinted in Thomson and Tait, "Natural Philosophy," Pt. II, p. 468.
[2] Am. Jour. Sci., vol. 45, 1893, p. 1.

surface gradient are assumed. He also found that the corresponding initial temperature of such a globe would be 1950° C.

Kelvin's last paper on a cooling earth [1] was read in 1897, and he there stated that after having worked out the problem of conduction of heat outwards from the earth by an elaborate method, he was not led to differ much from Clarence King's estimate. This he adopted as the most probable age and reduced his limits to between 20×10^6 and 40×10^6 years.

While King's earth is tidally stable, I confess that his solution of the problem seems to me to be fatally defective. He himself gives a temperature curve for the same earth at an age of 15 million years, and this earth shows a couche at a temperature above the melting point of diabase, this layer extending from a depth of 34 miles below the surface to 66 miles. According to Laplace's law of densities these two levels correspond respectively to densities of 2.85 and 2.93, and it seems certain that the material must consist chiefly of basaltic rocks. Thus the 15-million-year earth would be unstable and this instability would only just disappear at 24 million years. I am obliged to conclude that if an earth could cool in this way—if the crust could be prevented from breaking—the 24-million-year earth would only just have reached the "consistentior status" or the epoch of solidity.

The real earth, however, has been in a condition of tidal stability at least since the beginning of the Cambrian: for the strata are full of ripple marks, sands and pebbles rearranged by tidal currents, beach footprints and similar evidence of tides. Now oceanic tides would not exist upon a tidally unstable earth and, therefore, the consistentior status occurred long ago. It was the remoteness of this epoch that Kelvin attempted to calculate.

King gives data for only one earth which is satisfactory from this point of view. It had an initial temperature of 1230° C. and reached a surface gardient of 1° F. in 50.6 feet in 10 million years. It was solid almost from the beginning. But apart from the excessive brevity of the age, it seems to me that this earth must likewise be rejected. The temperature was insufficient to melt even diabase a few miles below the surface, much less andesites and rhyolites, while there is a mass of well-known evidence that the earth has been fluid at least to depths of many miles from its growing surface. This is shown by the general dependence of gravity on latitude, the nearly spheroidal shape of the earth, the oblateness of the interior layers of equal density and the conclusion reached by Kelvin,[2] Roche [3] and Wiechert [4] that a nucleus of constant high density (approxi-

[1] Trans. Victoria Institute, vol. 31, 1899, p. 11.

[2] "Natural Philosophy," Pt. II, p. 420. This article also appeared in the first edition of the "Natural Philosophy," 1867.

[3] Mém. Acad. Montpellier, 1882.

[4] Göttingen Nachrichten, 1897, p. 221.

mately the density of iron) surrounded by a shell of much smaller density (near 3) will satisfy the observations on precession, ratio of surface density to mean density and the ellipticity of sea level.

Considering the materials of which the earth is composed and the high pressures which must have existed at some distance from the surface at any stage of the earth's growth, it seems clear that very high temperatures must have prevailed within its mass, while for the reasons stated above, tidal instability at any epoch since the ocean came into existence is inadmissible. Hence the hypothesis of a constant initial temperature will not satisfy the conditions.

The question thus arises whether the initial temperature may be supposed to have been graduated in such a manner as to satisfy known conditions. I believe that this question may be answered affirmatively. Kelvin himself contemplated a very different distribution of temperature from the uniformity assumed in his equations. The earth, he said, "did in all probability become solid at its melting temperature all through or all through the outer layer"; "convective equilibrium of temperature must have been approximately fulfilled until solidification commenced"; and "the temperature of solidification will, at great depths, because of the great pressure there, be higher than at the surface if the fluid contracts . . . . in becoming solid."

Modified Problem.

If the initial temperature at the consistentior status increased with distance from the surface, it was probably according to some complex law intimately related to that of convective equilibrium, but the thickness of the shell which has been sensibly affected by cooling is very small. At a distance of 80 miles below the surface the temperature is probably now very near 99 per cent. of what it was at the consistentior status. Hence if a layer double this thickness is considered, the conditions which prevailed in the remainder of the earth are of no consequence. The inner part, with a radius of say 3840 miles, may have been originally at the temperature of ice or of the electric arc; it may conduct heat as well as silver or as ill as magnesia; in any case the influence on the outer surface would be insensible even after scores of millions of years. Now, though the temperature at the consistentior status did vary with distance from the surface according to a highly complex law, it is altogether probable that for so short a distance as 2 per cent. of the radius this law may be adequately represented by a straight line. This would be comparable with the superficial portion of Mr. Barus's curve, which is nearly rectilinear. Mr. Barus's experiments indicated that the relation between pressure and the melting point of diabase is a linear one, so that, had he confined his conclusions to a shell whose thickness was small relatively to

the radius, his melting point curve would have reduced to a straight line. Such a restriction in the circumstances is not objectionable and corresponds to the limitation of the problem of refrigeration as solved by Kelvin, whose formulas, strictly speaking, represent the cooling of a solid of indefinite extent bounded by a plane surface and not the cooling of a sphere. It can be and has been shown that the error introduced by neglecting the earth's curvature is insignificant.

It will be sufficient, therefore, to assume that the initial temperature of the earth increased in simple proportion to the distance from the surface, and this simplification renders it easy to modify the Fourier equation employed by Kelvin to satisfy this condition. In his solution an infinite homogeneous solid is supposed divided by a plane on one side of which, at the initial instant, the temperature has one uniform value, while on the other side it has another uniform value. The object of the second mass is to replace outer space and preserve a constant temperature in the dividing plane. This device may seem at first sight too artificial, but Kelvin proved that after a comparatively brief period the temperature of the surface of the globe would be affected to an entirely negligible extent by internal heat. Radiation and convection, or briefly "emissivity," accomplish substantially the same end as the hypothetical conducting solid, in that they dispose of the heat as fast as it reaches the surface excepting for a period of possibly a few thousand years after the surface of the globe solidified.[1]

Fourier's partial differential equation for the linear conduction of heat is

$$\frac{dv}{dt} = \kappa \frac{d^2v}{dx^2}$$

where v is temperature and x distance from a plane, while κ is the diffusivity which is assumed to be constant and known. Any value whatever of v which will satisfy this equation is a solution of some problem in conduction. In general the problem of finding a value of v which satisfies given boundary conditions is difficult, but in the particular case under discussion the appropriate form of v is easily arrived at. The equations

$$\frac{dv}{dx} = \frac{V}{\sqrt{\pi\kappa t}} e^{-x^2/4\kappa t} + c \qquad (1)$$

and

$$v - v_0 = V \frac{2}{\sqrt{\pi}} \int_0^{x/2\sqrt{\kappa t}} e^{-z^2} dz + cx \qquad (2)$$

[1] So far as the earth is concerned, the evaporation of water is the most important factor in the removal of heat from the surface to the upper regions of the atmosphere, or in what may be regarded as the emissivity of the globe. According to Sir John Murray's figures (Geochemistry, p. 53), the average annual rainfall less the run-off is about 70 centimeters, and substantially all of this is evaporated. The evaporation of 1 cubic centimeter absorbs about 591 gram calories and thus the total evaporation removes from the earth's surface some 13 times as much heat as the earth emits, the large residue being of course derived from the sun.

satisfy the partial differential equation when c, v_0 and V are constants, as may easily be tested by differentiation. If $c = 0$ they reduce to the forms used by Kelvin. Here v_0 represents the constant temperature at the surface of the cooling mass and V the initial temperature of the cooling mass at an infinitesimal distance from the surface. As will be proved in the next paragraph, c is the constant initial temperature gradient.

From the equations themselves it can be at once determined what boundary conditions are implied. When $t=0$, the upper limit of the integral in (2) becomes infinite, and the value of the integral itself is then $\sqrt{\pi}/2$; consequently when $t = 0$ and x is a positive quantity, the initial distribution of temperature in the real solid is represented by

$$v - v_0 = V + cx$$

while in the imaginary solid replacing outer space at the same instant

$$v - v_0 = -(V + cx)$$

Hence equations (1) and (2) fulfil the conditions demanded by the modified problem under discussion, and represent the cooling of a body in which the initial temperature increased from the surface value, V, in simple proportion to the depth, x.

The superficial temperature gradient at any time is found by making $x = 0$ in (1) and is expressed by

$$\left(\frac{dv}{dx}\right)_0 = \frac{V}{\sqrt{\pi\kappa t}} + c \qquad (3)$$

In Kelvin's solution this quantity as well as κ and V is regarded as known, while c is made equal to zero, so that (3) gives the required age. In 1862 it seemed both unobjectionable and inevitable to rely on the surface gradient determined by observation in determining the age of the earth; but it is now known that this gradient is affected by radioactivity, and, therefore, that it cannot be trusted. It is the special purpose of this paper to dispense with the employment of the surface gradient. This will be accomplished by taking advantage of Mr. John F. Hayford's level of isostatic compensation, which lies far below the level at which radioactivity can affect the supply of heat.

If appropriate values of the constants can be found, equations (1) and (2) can be computed for any desired age, and this computation is an easy task because the value of the definite integral in (2) has been tabulated by various mathematicians, the most complete table being by Mr. James Burgess and printed in 1900.[1]

Kelvin employed a diffusivity, κ, of 400, using the British foot and the year as units. In c. g. s. units this would be 0.01178. This value was obtained from experiments on the trap rock of Calton Hill, the sand of an

[1] Trans. R. S. Edinburgh, vol. 39, 1900, p. 257.

experimental garden and the sandstone of Craigleith quarry, all at Edinburgh. Different weights were given to these observations, but how is not explained. Now, in considering the diffusivity of the earth it does not seem to me that the ragged pellicle of detrital matter on its surface need be considered. Over large areas it is absent and in most places the sedimentary rocks are saturated with water, so that their own intrinsic diffusivity is a minor feature of the flow of heat. The great bulk of the rocks in the shell affected by cooling are massive and at least comparable with the trap of Calton Hill, which is chiefly composed of Carboniferous basalt and andesite. The conductivity of this rock was observed by Forbes and Thomson (Kelvin) for no less than eighteen years; the thermal capacity was determined by Regnault, so that the value of the diffusivity, 0.00786, is undoubtedly very accurate. It does not stand alone. A committee of the British Association,[1] Herschel and Lebour, reported for whin and traps $\kappa = .0067$, and for serpentine from .00594 to .0073, while Ayrton and Perry got for porphyritic trachyte .0103. I do not think a better choice can be made than the Calton Hill trap, and its diffusivity with the meter and year as units is the value which will be assumed here, *i. e.*, $\kappa = 24.8037$.

That κ varies with temperature and with pressure is probable. That in iron it decreases with increasing temperature is known and analogy would point to the conclusion that it should increase with pressure. Possibly diffusivity is simply related to density and for the same or similar rocks tends in the earth to a nearly constant value. At present it seems unavoidable in this problem to regard it as constant.

The outer portion of the earth is composed of various rocks which are believed to be arranged roughly in the order of density. If so the peridotites underlie the basaltic rocks, while the andesites and rhyolites overlie them. These latter are less fusible than diabase. How deep the level lies which would answer to the upper surface of the basaltic rocks cannot be told with certainty. The best that can be done is to assume that Laplace's law of density is valid for a few score miles from the surface and to consider roughly the effects of heat and pressure. In this way I have reached the conclusion that at about 40 miles, or 0.01 times the radius, where the density should be 2.86, the temperature perhaps 1300° C. and the pressure 17,400 atmospheres, basaltic rocks may begin to appear in place. A pressure of 13 or 14 atmospheres per degree centigrade is probably of the order of magnitude needful to preserve constancy of volume in a heated solid, while at atmospheric pressures the densities of basaltic rocks are from 2.85 to 3.10, with minor exceptions. The outer crust to a depth of 40 miles is thus probably less fusible than basalt.

[1] Brit. Assoc. Ad. Sci., 1881.

As was pointed out above, the line representing the melting point of diabase in terms of depth as determined by Mr. Barus may be taken as rectilinear for depths up to a hundred miles, and is then represented by what I may call the diabase line,

$$y=1170^\circ+\frac{430}{.01r}x=b+px$$

where r is the radius of the earth, and according to the results of the last paragraph the original temperature distribution in the globe must be such that only the layer of rock within 40 miles of the surface was heated to a higher point than that at which diabase would melt. Thus V being the original surface temperature and the original temperature at distance x being represented for distinction by u,

$$u=V+cx$$

According to a preceding paragraph it is probable that y and u should have the same value at $0.01r$ or 63,710 meters from the surface, but the discussion can be made a little more general by supposing the intersection to be at a depth nr. Then

$$c=p-\frac{V-b}{nr} \qquad (4)$$

It is easy to perceive that whatever values of the constants and the age are chosen, the temperature curve will have one and only one tangent which is parallel to the diabase line. Of course the point of tangency is that at which the curve approaches the melting point of diabase most closely or at which the additional temperature which would be required to melt diabase is a minimum. It is at this level of tangency that any access of temperature due to the dissipation of mechanical energy or to other causes is most likely to produce fusion at depths where the rock is diabasic. If the constants are assumed at any value and the courses of the curves are considered for various periods of time, it is easily seen that the point of nearest approach to the diabase line sinks to greater depths as time elapses.

Now, strains must exist in the earth at all times. They may be and are partially relieved by rupture and by solid flow, but most completely by fusion. Thus in an earth the cooling of which is represented by (2) such strains as may be incident to upheaval and subsidence and to orogeny will probably be most completely relieved at the slowly sinking surface of easiest fusion.

Messrs. Tittmann and Hayford have recently discussed the whole body of geodetic data for the United States and have shown that the deflections of the vertical are best accounted for by the hypothesis that isostatic com-

pensation is uniformly distributed and is complete at a depth of 114 kilometers or 71 miles from the surface.[1]

I, therefore, adopt the hypothesis that the tangent of the temperature curve, or equation (1), is parallel to the diabase line at 114 kilometers from the surface.

V is the value of the original temperature of the earth at its surface. As was pointed out above, this must have been high enough to fuse rocks more refractory than diabase and was probably about equal to the temperature of the hottest eruptions which now reach the surface of the earth. It seems to me that 1300° is a reasonable estimate. This is considerably below the melting point of pure iron and lower than the blast furnace, but above the melting point of copper (1065°), which lavas are known to fuse, and of Barus's diabase (1170°). So far as I know, no precise determinations have yet been made of the temperatures at which lavas issue from their vents.

To make the use suggested above of the level of isostatic compensation let its depth be represented by x_1 and in equation (1) let $(dv/dx)_1 = p$, the gradient of the diabase line. Then since p also appears in the value of c, p disappears and $(dv/dx)_1 - c =$

$$\frac{V-b}{nr} = \frac{V}{\sqrt{\pi\kappa t}} e^{-x_1^2/4\kappa t}$$

On the assumptions here made this equation determines the age of the earth and this age is independent either of the gradient of Mr. Barus's diabase line or of the initial temperature gradient. The constants involved are the initial surface temperature (V), the melting point of diabase at the earth's surface (b), the diffusivity (κ), the distance from the surface of the top of the diabase couche (nr) and the depth of the level of isostatic compensation (x_1). The surface temperature gradient does not in any manner enter into this expression, which is thus wholly distinct from that employed to determine the age by Kelvin.

Numerical Results.

Solving for V and substituting the numerical values for π, κ, r and x_1 gives

$$\frac{1}{V} = \frac{1}{1170^0}\left(1 - \frac{721.720n}{\sqrt{t}} e^{-\frac{130.99\times10^6}{t}}\right)$$

in which n is left indeterminate to facilitate any variations in the depth of the top of the diabase couche thought desirable. The form of the equation is such that t is almost necessarily taken as the independent variable, but that is of no consequence.

---

[1] Rep. to 15th general conference of the International Geodetic Assoc., Washington, 1906.

In the Coast and Geodetic Surv. Report on the Figure of the Earth and Isostasy, 1909, Mr. Hayford gives the depth of compensation ("solution G") at 113.7 kilometers. In my paper in Science, vol. 27, 1908, p. 227, this depth was stated by a blunder in copying at 140 kilometers, but the correct value was used in the computations.

When V is computed or assumed c may be found from (4) and the surface gradient is then ascertained from (3). Taking n at 0.01 as indicated by Laplace's law I now get the following table of related values:

T	30.	50.	55.	60.	65.	100.
V	1190.°	1264.	1286.	1307.	1329.	1453.
c	0.00644	0.00527	0.00493	0.00459	0.00426	0.00231
$1/c$	155.^{m}	190.	203.	218.	235.	433.
G°C.	32.°2	39.2	40.7	42.2	43.6	53.3
G°F.	58.°7	71.4	74.2	76.9	79.5	97.1

T is the age in millions of years; V is the initial surface temperature; c is the initial gradient of internal temperature and $1/c$ gives this gradient in terms of meters per degree centigrade. G° C. is the final surface gradient in terms of meters per degree centigrade and G° F. is the same gradient in terms of feet per degree Fahrenheit.[1]

In all of these earths the upper surface of the diabase couche is supposed to be at one one-hundredth of the radius from the surface, or 63,710 meters, but another assumption will be made below. All of the excess of temperature curves have tangents parallel to the diabase line at a depth of 114,000 meters. Tidal stability is provided for at all times by the equations; for the temperature curves never cross the diabase line excepting within 40 miles of the surface, or within the shell of more refractory rocks.[2]

Of the six earths computed the one whose initial temperature comes nearest to 1300° C. is that of the 60-million-year earth, and it is the one

[1] Mr. Hayford's latest value for the level of isostatic compensation appeared while this paper was in press. It is contained in Supplementary Investigation of the Figure of the Earth and Isostasy, Coast and Geod. Surv., 1910, and is 120,900 meters. This new value would reduce the initial temperature of a 60 x 10^6 globe to 1272°, or give for a globe whose initial temperature was 1300° an age of 68 million years, with a surface gradient of 1° C. in 44 meters.

[2] Immediately after the primitive consolidation of the earth it is almost certain that a period of aqueo-igneous fusion supervened, as I pointed out in Bull. Geol. Soc. Amer., vol. 19, 1908, p. 142. This was the period of the formation of the granitoid rocks and it may have been of rather brief duration. The formulæ of the text are applicable to the very early stages of the cooling of a large lava field rather than to the very first part of the refrigeration of the globe, but after a time so brief as to be insignificant compared with the earth's age the equations used would apply. To illustrate this point fancy the hypothetical earth whose initial temperature V was 1307° with gradient $c = 0.00459$ to have cooled until it emitted just heat enough to raise the temperature of a sheet of water 1 meter deep 1° in 1 day. This means an emission of 36,524 gram calories per annum, and this would be totally expended by an evaporation of a layer of water about 62 centimeters deep. This is considerably less than the present mean evaporation on continental areas. Hence there is no difficulty in imagining the surface of the earth at this stage kept constant by emissivity, including evaporation, and from that period on the formulæ may be considered as applicable.

Now if the theory held good also prior to this period, the lapse of time since the consistentior status would be only a trifle more than 28 years, the gradient would be nearly 28° per meter and the rock would be red-hot, or at 500°, only 18 meters from the surface. These results depend on the conductivity of the rock (or the diffusivity multiplied by the thermal capacity) which for the Calton Hill trap is 0.00415 in c. g. s. units, the heat emitted per second per square centimeter being the product of the surface gardient and the conductivity. Doubtless the real duration of this initial stage was longer than 28 years. If it were a hundred times as long, or even 1000 times, the age of the earth would be substantially the same as if the formulæ accurately represented the entire process.

which appears to me most probable. The most evident objection to it is the low surface gradient of 1° F. in 77 feet, while Kelvin took 1° F. in 50.6 feet and King stated that in 1893 the last published value as reduced from all available data by the British Association committee was 64 feet per degree Fahrenheit. King himself considered 75 feet a maximum. To me, however, it does not seem that an average value is what is required. In discussing the cooling of the earth disturbing causes must be eliminated as far as possible. Now several causes must contribute more or less to raise the temperature of rocks near the surface; for example, thermal springs, volcanic heat, the dissipation of mechanical energy by faulting or solid flow, the liberation of heat in the decomposition of minerals and radioactivity. So far as I know, the only causes which can lead to a deceptively low gradient in rocks of a given type are the neighborhood of large bodies of cold water and abnormally high diffusivity. Furthermore, to include gradients observed in sedimentary rocks seems to me to complicate the problem unnecessarily. The gradients which should serve as a guide are those in massive rocks, especially the nearly anhydrous basaltic, andesitic and rhyolitic massives. All cases where there are local evidences of heat due to thermal springs, etc., should be excluded, and when for a normal rock the gradient is unusually high, it should be considered as suspicious. In short, for the present problem the lower gradients in massive rocks are those most likely to give a correct value of the earth's age.

Several writers have made suggestions of this kind, but Mr. Johann Koenigsberger[1] has given the only detailed discussion of the matter known to me, pointing out that the characteristic gradients are those observed in nearly level, inland regions, in chemically unaltered rocks. Of such he gives 26 cases, ranging from 1° C. in 27.8 meters to 1° in 37.9 meters. Five of these average 1° in 37.7 meters, so that, in round numbers, 1° in 38 meters seems to me best to represent the true terrestrial gradient. Comparing this gradient with the 1° in 42.2 meters computed for the 60-million-year earth leaves a difference of 1° in 385 meters to be accounted for by exothermic chemical action. This is no doubt an inaccurate remainder, but it is probably of the order of magnitude of the correction appropriate to radioactivity and similar causes.[2]

Mr. Koenigsberger in the same paper has also shown that the temperatures observed in the Swiss railway tunnels can be computed from Fourier's equations and average superficial temperature gradients when the topographic forms are duly represented in the formulæ. Hence it is not needful to assume radioactivity in order to account for these phenomena.

---

[1] Congrès géolog. Intern., tenth session, Mexico, Compte Rendus, 1907, p. 1127.

[2] See "Relations of Radioactivity to Cosmogony and Geology," Bull. Geol. Soc. Amer., vol. 19, 1908, p. 113.

The least satisfactory of the assumptions made in the foregoing discussion of refrigeration is that the depth of the diabase couche is 40 miles or $0.01r$. This was estimated from Laplace's law, but that is a mere approximation or at best a mean. In order to test the consequences of a variation in the thickness of the refractory shell (nr) I have also computed some cases for $nr = 0.0075r$, or say 30 miles. Of these I will give only that appropriate to an initial surface temperature of $V = 1300°$. The results are:

T	70.
c	0.00403
$1/c$	248.
G°C.	46.3
G°F.	84.3

Thus the age falls out notably greater and the gradient lower, leaving double the margin for chemical heat estimated in the case of the 60-million-year earth. While these results are less probable than those for the younger earth, they do not seem impossible and, in my opinion, 70 million years may be taken as a maximum value of the age of the earth as determined from refrigeration.

With such constants as are now available it seems to me that the age of the globe considered as a cooling body must be between 70 million and 55 million years, limits not differing greatly from those found by other means in the earlier part of this publication.

Conclusion.

In the stratigraphical method of determining the age of the ocean the weak point is the uncertainty of the duration of pre-Cambrian time. The best determination of the date of the base of the Cambrian seems to be that by Mr. Walcott, who places it at 27,640,000 years ago. The order of magnitude of the pre-Cambrian period is probably the same, so that stratigraphy indicates an age of the ocean of, say, between 50 and 65 million years. This is in accord with Mr. Sollas's most recent results, for he regards 80 million as a maximum without being able to give a definite account of nearly so long a period.

Considering sodium accumulation as an asymptotic process, as it unquestionably is, the weak point is the possibility that the primitive ocean was salt, or that there have been continents in the oceanic basin. These possibilities do not affect an estimate of the maximum age, 74 million years, but preclude a definite minimum. Assuming that neither of these possibilities was realized, the minimum would be about 46 million years.

Refrigeration, so dealt with as to exclude tidal instability, and computed on the basis of Mr. Hayford's level of isostatic compensation, with-

out employing as a datum any observed superficial temperature gradient, yields results which can hardly be forced above 70 million or below 55 million years. The weak point here is our ignorance of the depth of the top of the diabase couche; but if Laplace's law of density holds true, the limits would be about 65 and 55 million years.

These three methods seem to be mutually confirmatory and to give results which converge towards some value near 60 or perhaps 65 million years.

This being granted, it follows that radioactive minerals cannot have the great ages which have been attributed to them. Only something like a tenth of the heat emitted by the earth can be ascribed to radioactivity plus all other exothermic chemical transformations; the remaining nine-tenths is heat due to compression.

SMITHSONIAN MISCELLANEOUS COLLECTIONS

VOLUME 56, NUMBER 7

DESCRIPTION OF A NEW SUBSPECIES OF AFRICAN MONKEY OF THE GENUS CERCOPITHECUS

BY

D. G. ELLIOT

(PUBLICATION 1937)

CITY OF WASHINGTON

PUBLISHED BY THE SMITHSONIAN INSTITUTION

June 11, 1910

DESCRIPTION OF A NEW SUBSPECIES OF AFRICAN MONKEY OF THE GENUS CERCOPITHECUS

By D. G. ELLIOT

The species of monkey here described was obtained by the Smithsonian African Expedition in British East Africa, in 1910, and I am indebted to the authorities of the U. S. National Museum for the privilege of making it known to naturalists.

CERCOPITHECUS CENTRALIS LUTEUS, subsp. nov.

Type locality.—Wambugu, southwest of Mount Kenia, British East Africa. Type, U. S. National Museum, No. 163086. Original No. 7190.

General characters.—Remarkable for the buff underparts of the body.

Color.—Black line formed of long hairs over eyes, succeeded by a cream buff broader band; rest of head and upper parts of body ochraceous buff, the hairs being grayish at base, then banded with black and ochraceous buff and tipped with black, but the paler color predominates the dark; flanks paler, outer side of arms and thighs dark gray, the hairs tipped with white; outer side of legs to ankles smoky gray, hairs white tipped; chin black; cheeks, throat, and entire underparts of body and inner side of limbs buff; hands black; feet iron gray; tail at base above like back, then gray rather whitish tips to hairs, and tip black; beneath whitish.

Measurements.—Total length, 990 mm.; tail, 570; foot, 120; ear, 28.

Skull.—Total length, 90.7; occipito-nasal length, 79.4; hensel, 60.3; zygomatic width, 61.1; intertemporal width, 43.6; palatal length, 31; median length of nasals, .94; length of upper molar series, 23.8; length of mandible, 67; length of lower molar series, 29.9.

This species is somewhat similar to *C. c. johnstoni*, from the south side of Mount Kilmanjaro, but differs altogether in its buff underparts and inner side of limbs, thus contrasting strongly with the yellowish white of *C. centralis* and the grayish white of *C. c. johnstoni* and *C. c. whytei*. Two examples, both young adults, females, were in the collection.

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 56, NUMBER 8

NOTES ON A HORN-FEEDING LEPIDOPTEROUS LARVA FROM AFRICA

WITH TWO PLATES

BY
AUGUST BUSCK

(PUBLICATION 1941)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
JULY, 1910

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

NOTES ON A HORN-FEEDING LEPIDOPTEROUS LARVA FROM AFRICA

By AUGUST BUSCK

(With Two Plates)

Among the zoological objects secured by the Smithsonian African Expedition, under the direction of Col. Theodore Roosevelt, is a skull of a large Water Antelope (*Cobus* sp.) on the magnificent (over two feet long) horns of which was a large number of curious larvæ tubes of a microlepidopteron, *Tinea vastella* Zellar.

The skull is evidently not of an animal shot by the party, but was picked up on the ground. It bears the label No. 6825 S. N'guasso Nyiro River, British East Africa, June, 1909.

The evidence of moth-infestation on the horns was very striking and is well illustrated in the two excellent photographs, reproduced on plates 1 and 2, for which I am indebted to Mr. T. W. Smillie. It consists of large bunches of dark brown finger-like tubes each about ¼ of an inch in diameter and anywhere from ½ to 2½ inches long. These tubes are very tough, being made of silk, into which is incorporated earth and chewed-up fiber of the horn; the interior of the tubes is smooth gray silk. The tubes are closed at their outer end like the fingers of a glove and are connected at their basal end with round holes leading into galleries in the horn, where the larvæ found their nourishment.

Accounts of similar infestations of horns of ruminants have occurred from time to time and they seem particularly common in Africa.

There has been some difference of opinion among the observers about the possibility of the horns of living ruminants becoming infested and some of the evidence seems sufficiently conclusive that such infestation may occasionally occur. The substance of the horn is the same in the living animal as in the dead, and it seems at least possible that the moth may deposit its eggs on the horns of a resting or sleeping animal, and that the larvæ in such case could develop successfully, but this is undoubtedly the exception and the species normally only attacks the horns of dead animals.

Lord Walsingham has given a review of the subject (Proc. Ent. Soc., London, 1881, pp. 238-241) but no figure has been given of this infesta-

this except the rather primitive sketch accompanying the account of Mr. N. H. Corquodale on the infested horns of a hartebeest in Nature, Vol. 58, 1898, p. 140. This sketch differs in some particulars from the present specimens: it figures the larvæ tubes as single and coming from all parts and sides of the horns, while in the present specimen they are more or less united and matted together, though a few single tubes were found; more important than this, the present specimens were confined to the side of the horn, which had evidently been toward the ground, and besides particles of the horn they had incorporated in them a good proportion of earth. The explanation of this may be that Mr. Corquodale's horns have become infested while or just before they were boxed for shipment and that the larvæ constructed their tubes in different directions, due to the varying position of the box, which was no doubt frequently changed during transit.

While the present cases presumably are the work of *Tinea vastella* Zellar, which seems to be common everywhere in Africa, and which is credited with all the recorded infestations from Africa, it should be remembered that other species of the genus have similar habits, and that more than one species may be involved. Stainton described one species, *Tinea orientalis*, bred from horns in Singapore, and the writer has seen similar work in horns of domestic cattle lying on the ground at Fajardo, Porto Rico; in fact the habit is parallel with and very similar to those of the common tubemaking cloth moth *Tinea pellionella* Linné.

HORN-FEEDING LEPIDOPTEROUS LARVA

HORN-FEEDING LEPIDOPTEROUS LARVA

SMITHSONIAN MISCELLANEOUS COLLECTIONS

VOLUME 56, NUMBER 9

DESCRIPTIONS OF SEVEN NEW SPECIES OF EAST AFRICAN MAMMALS

WITH THREE PLATES

BY

EDMUND HELLER

Field Naturalist, Smithsonian African Expedition

(PUBLICATION 1942)

CITY OF WASHINGTON

PUBLISHED BY THE SMITHSONIAN INSTITUTION

July 22, 1910

WASHINGTON, D. C.
PRESS OF JUDD & DETWEILER, INC.
1910

DESCRIPTIONS OF SEVEN NEW SPECIES OF EAST AFRICAN MAMMALS

(With Three Plates)

By EDMUND HELLER

FIELD NATURALIST, SMITHSONIAN AFRICAN EXPEDITION

The seven species and subspecies of mammals here described were collected by members of the Smithsonian African Expedition. This paper is the ninth dealing with the results of the expedition.

TATERA VARIA, new species

Type from the Loletai Plains, Southern Guaso Nyiro River, Sotik District, British East Africa; adult male, number 162249, U. S. Nat. Mus.; collected by J. A. Loring, June 15, 1909; original number 6338.

Coloration.—Dorsal coloration tawny ochraceous overlaid faintly with blackish posteriorly; sides lighter, pure ochraceous without any black intermixture, the ochraceous not very sharply defined from the pure white of the underparts; area between eye and ear, and spot behind ear whitish. Underparts pure white, the hair white to the roots. Feet white. Ears dusky, very sparingly haired. Tail clothed with white hair except the dorsal surface of the anterior half, which is tawny like the back.

Measurements.—Head and body, 169 mm.; tail, 239; hind foot, 43. Skull: condylo-nasal length, 45.5; basilar length, 36.5; palatilar length, 22; zygomatic breadth, 24; nasal, 20; interorbital constriction, 8; diastema, 13.5; maxillary toothrow, 7.5.

Most closely allied to *fallax*, from which it is distinguishable chiefly by its longer pencillate tail and the larger audital bullæ.

This species shows great variation in the character and number of the longitudinal grooves of the upper incisors. This variation extends from incisors which show no grooves to specimens showing as many as three grooves to each incisor. In a series of fourteen fully adult skulls from the same locality there are five specimens which show no indication of grooving even under magnification, three which show only one groove, five which have two grooves to each incisor, and one which possesses three grooves. The grooving

in all these specimens is rather shallow, and so faint that usually only one groove is evident without magnification.

TATERA POTHÆ, new species

Type from Potha, Kapiti Plains, British East Africa; adult female; number 161716, U. S. Nat. Mus.; collected by J. A. Loring, April 30, 1909; original number 6013.

Coloration.—Above tawny-ochraceous lightly lined with blackish hairs posteriorly. Tip of snout black. Eyes narrowly ringed with black; a white spot between eye and ear and a partially hidden one at posterior base of ear. Color of sides of head and body changing from the darker dorsal area through ochraceous to ochraceous-buff, but sharply defined against the pure white of the underparts. Ears thinly haired with blackish. Feet white; inside of hind limbs about ankle blackish. Underparts pure white, the hair white to the roots. Tail above brownish, the color deepening and spreading to under side on tip, where it becomes black; below, anteriorly, ochraceous like sides.

Measurements.—Head and body, 152 mm.; tail, 203; hind foot, 40. Skull: condylo-nasal length, 42.5; basilar length, 33; zygomatic breadth, 21.5; interorbital constriction, 7; nasal, 20; diastema, 11.2; maxillary toothrow, 7.

This form is most closely allied to *vicina* of Kitui, which is a smaller-footed and darker-colored race with smaller teeth. From *mombasæ* it differs in its shorter ears, much heavier and longer hair and the absence of the median dark stripe on the inferior surface of the tail.

EPIMYS PANYA, new species

Type from Juja Farm, Athi Plains, British East Africa; adult male; number 161886, U. S. Nat. Mus.; collected by J. A. Loring, May 23, 1909; original number 6220.

Coloration.—Above buffy, overlaid by black, the individual hairs medially buffy brown with black tips, interspersed with longer black hairs. Sides purer buff, merging gradually into the grayish of the under parts. Under parts whitish with a faint buffy tinge, the hairs slaty at base. Feet white. Ears blackish and appearing quite naked, but clothed sparingly by minute hairs. Tail naked, uniform dusky.

Measurements.—Head and body, 119 mm.; tail, 119; hind foot, 22.5. Skull: condylo-nasal length, 29.5; basilar length, 23.5; zygomatic breadth, 14.4; nasal, 11.8; interorbital constriction, 4; diastema, 8; maxillary toothrow, 5.1.

Closely allied to *hildebrandti* of the coast lowlands, which is a larger rufous brown form, and to *ugandæ*, which is darker and smaller. This is the most abundant mouse of British East Africa and the only native species which enters houses.

EPIMYS NIVEIVENTRIS ULÆ, new species

Type from the Ulu Kenia Hills, British East Africa; adult female; number 162887, U. S. Nat. Mus.; collected by J. A. Loring, November 19, 1909; original number 8221.

Coloration.—Above wood brown becoming lighter on the sides, but sharply defined from the pure white of the under parts; hairs of dorsal region wood brown, with dark blackish tips, the median dorsal area darkest. Ears dusky, clothed sparingly with minute brown hairs. Feet and under parts pure white, the hairs everywhere white to the roots. Tail dusky above, whitish below, but not sharply bicolor; clothed with brown hair, which becomes somewhat more abundant at tip, but not distinctly pencillate.

Measurements.—Head and body, 88 mm.; tail, 128; hind foot, 19.5. Skull: condylo-nasal length, 26.5; basilar length, 20.8; zygomatic breadth, 14; nasal, 11; interorbital constriction, 4.2; diastema, 7; maxillary toothrow, 4.4.

Allied to *subfuscus*, Osgood, of the Rift Valley, from which form it differs in smaller proportions and the greater extent of the white of the under parts. This mouse occurs abundantly on the rocky kopjes of the Athi Plains.

EPIMYS ENDOROBÆ, new species

Type from the western edge of the Mau Forest, 25 miles north of Edoma Ravine, altitude 8,600 ft.; adult male; number 162888 U. S. Nat. Mus.; collected by Edmund Heller, November 27, 1909; original number 1261.

Coloration.—Median dorsal area from snout to base of tail hair brown, darkest on mid-line of back and merging on sides of head and body to ochraceous buff; lower sides fulvous, sharply defined from the whitish of the under parts. Ocular region and sides of snout blackish. Under parts white, tinged lightly with buffy, the hair broadly blackish slate at base. Feet white. Ears blackish, clothed sparingly with minute brownish hairs. Tail quite naked at base, dusky, becoming hairy toward tip, the terminal half inch white.

Measurements.—Head and body, 100 mm.; tail, 151; hind foot, 20; ear, 19.5. Skull: condylo-nasal length, 28.5; basilar length,

22; zygomatic breadth, 14; nasal length, 10.8; interorbital constriction, 4; diastema, 7.5; maxillary toothrow, 4.8.

Closely allied to *denniæ*, Thomas, of Ruwenzori, from which it may be distinguished by its much darker coloration, smaller ears, and larger molars.

This species is found only in the forest region, where it is everywhere associated with *E. peromyscus*.

TACHYORYCTES REX, new species

Type from the western slope of Mt. Kenia, altitude 10,000 ft.; adult male; number 163088, U. S. Nat. Mus.; collected by J. A. Loring, October 7, 1909; original number 7840.

Coloration.—Dorsal coloration brownish fulvous, overlaid faintly with blackish posteriorly, tip of muzzle blackish; hair everywhere dark slate at base. Under parts lighter, more tawny fulvous, with the plumbeous showing through conspicuously; small area about mouth white; throat blackish. Feet broccoli brown, the toes whitish. Tail dusky above, whitish below.

Measurements.—Head and body, 232 mm.; tail, 59; hind foot, 31. Skull: condylo-basal length, 54.5; basal length, 51; zygomatic breadth, 39; nasals, 23 x 7.2; length of bullæ, 11.8; diastema, 20; maxillary toothrow, 10.5; diameter of m^1, 4.

Size large, exceeding all other East African races. This species is most closely allied to *audax*, of the Aberdare Range, in skull characters. Teeth actually larger, but proportionately somewhat less, than those of *audax*. Nasals much longer and with lateral reentrant angles present. In coloration this form is somewhat lighter than *audax*, and agrees with it further in seldom being subject to melanism. Compared to *annectens*, of Naivasha, which nearly equals it in size, the teeth and nasal bones are markedly larger, the basioccipital is much broader between the bullæ and the mandible, has a much larger condyle and coronoid process, with the incisor capsule placed very much farther forward. It is evident that in the alpine races of this genus the teeth are much enlarged.

This is an extremely abundant species on Mt. Kenia, where it inhabits a narrow zone at the upper edge of the bamboo forest where the moorland country first makes its appearance. The species is not found immediately below this area in the bamboo or yew forests, but another species appears on the grassy plains at the base of the mountain.

CROCIDURA ALPINA, new species

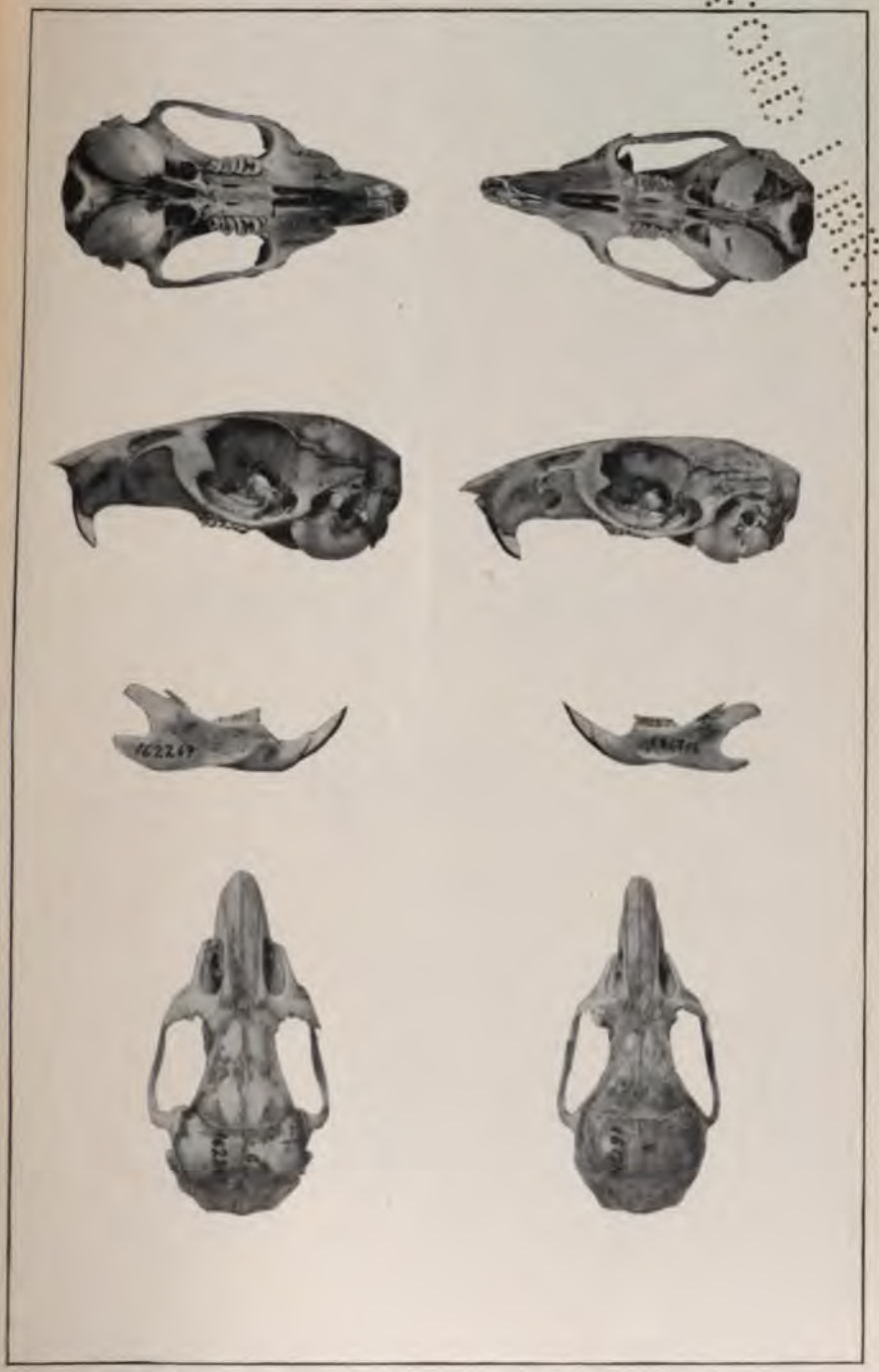
Type from the west slope of Mt. Kenia, altitude 10,000 ft., British East Africa; adult female; number 163089, U. S. Nat. Mus.; collected by J. A. Loring, October 4, 1909; original number 7728.

Coloration.—Dorsal coloration Prout brown, changing on lower sides gradually to the buffy gray of the under parts. Feet lighter, wood brown. Tail above like back; below light buffy, but not sharply bicolor.

Measurements.—Head and body, 65 mm.; tail, 39; hind foot, 11. Skull: condylo-incisive length, 16.2; breadth of brain-case, 7.5; depth of skull at bullæ, 4.6; length of upper toothrow, 7.

This species is closely allied to *allex*, from which it may be distinguished by its much flatter skull (one-half millimeter less), relatively small upper middle incisor, and by its bicolor tail and lighter coloration generally.

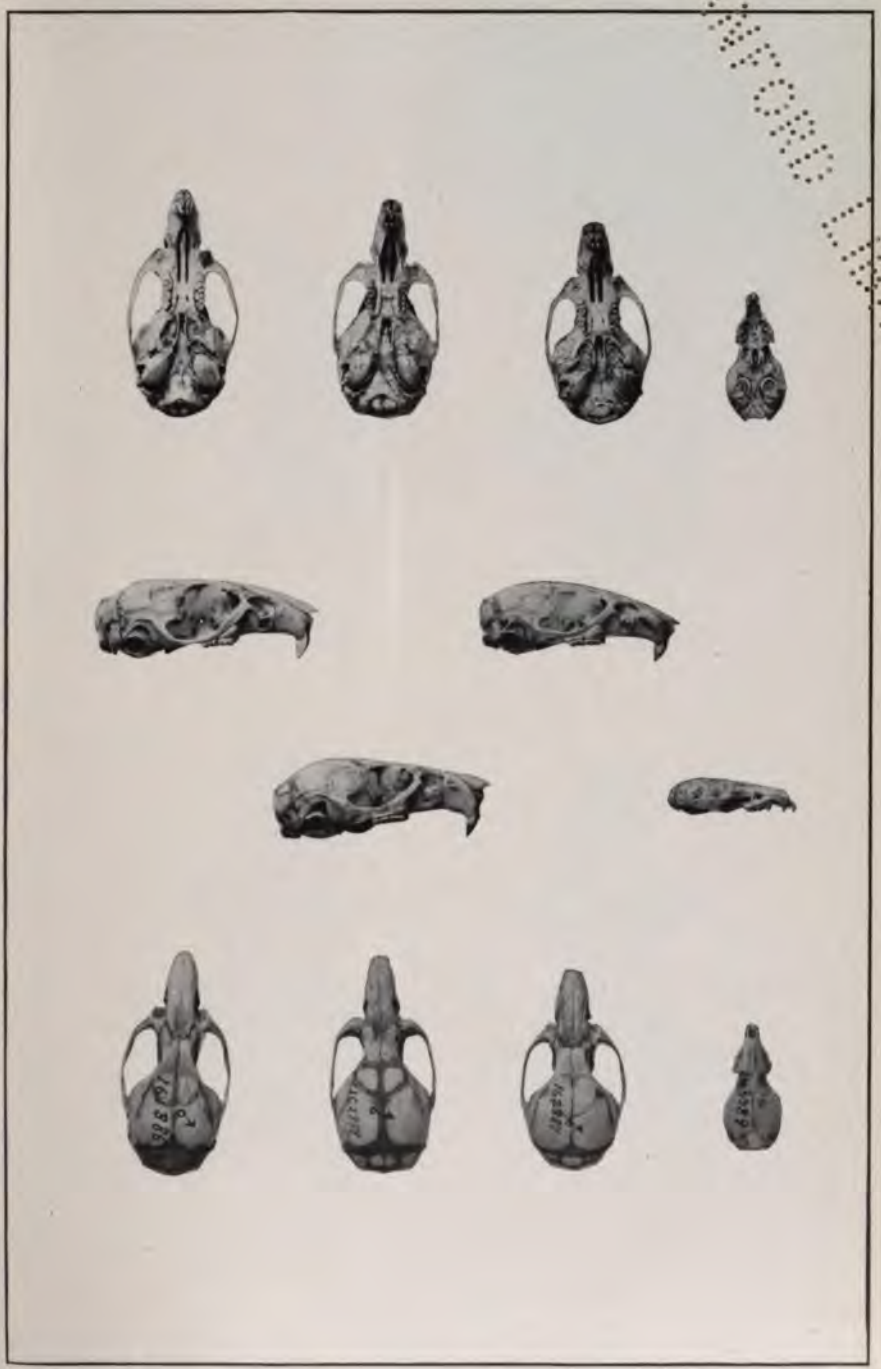
It is surprising to find this pygmy shrew in the alpine region of Kenia. The closely allied *allex* inhabits the lake district of Naivasha, the intermediate region about the base of Kenia being inhabited by the much larger *hildegardeæ*. The range of this species extends from 10,000 to 13,700 ft.—that is, from the upper limit of the bamboo forest to the lower part of the giant *Senecio* zone. Through most of this extent it is associated with the giant Crocidura, *C. nyansæ*, attaining, however, a somewhat higher altitude than this species.



TATERA VARIA HELLER
Type. Natural size

TATERA POTHÆ HELLER
Type. Natural size

Property of Library



EPIMYS PANYA HELLER
Type. Natural size

EPIMYS NIVEIVENTRIS ULÆ HELLER
Type. Natural size

EPIMYS ENDOROBÆ HELLER
Type. Natural size

CROCIDURA ALPINA HELLER
Type. Natural size

TACHYORYCTES REX HELLER
Type. Natural size

Digitized by Google

SMITHSONIAN MISCELLANEOUS COLLECTIONS

VOLUME 56, NUMBER 10

NEW LANDSHELLS FROM THE SMITHSONIAN AFRICAN EXPEDITION

BY

WILLIAM HEALEY DALL

(PUBLICATION 1945)

CITY OF WASHINGTON

PUBLISHED BY THE SMITHSONIAN INSTITUTION

July 22, 1910

WASHINGTON, D. C.
PRESS OF JUDD & DETWEILER, INC.
1910

NEW LANDSHELLS FROM THE SMITHSONIAN AFRICAN EXPEDITION

By WILLIAM HEALEY DALL

The landshells collected by the Smithsonian African Expedition, under the direction of Col. Theodore Roosevelt, were chiefly of the characteristic East African types, *Limicolaria* and the like, which will take a good deal of careful study to work out, since the species are variable and many names have been applied to them. It appears, however, that there are three species which are undescribed and sufficiently well marked to render descriptions desirable in advance of the proposed general report on the collection. Two of these belong to a special group under *Buliminus* (senso lato), and the other is a *Limicolaria*.

FIG. 1

BULIMINUS ROOSEVELTI, new species (Fig. 1)

Shell short, stout, solid, the last whorl much the largest, the color varying from a vinose purple-brown to opaque white; nucleus of about three whorls, smooth and polished, merging, without marked interruption, into the sculpture of the four subsequent whorls; these have minute retractive wrinkles, feebly fasciculated, stronger and more distant on the early whorls, closer and finer on the later ones, with an obscure tendency toward minute puckering at the suture; these axial wrinkles are broken into granules or segments on the last two whorls by spiral depressed lines, to which are added on the last half of the last whorl more or less irregular, sometimes angular,

sharp, short incisions, tending in the same direction; suture well marked, more or less minutely undulated by the sculpture; whorls inflated, the last slightly descending toward the aperture, the base swollen, with no umbilicus; the aperture rounded-quadrate, strongly expanded and reflected, though with only a thin glaze over the body; peristome yellowish white, the throat purple-brown, or both may be lighter in some specimens; pillar short, stout, straight, with no indication of a fold, the lip behind it heavy and folded over on the base. Height of shell, 33.0; of last whorl, 22.0; of aperture, 19.0; max. diameter, 20.5 mm.

Collected by Lt. Col. E. A. Mearns on Mt. Kenia, at the height of 8,000 to 10,500 feet above the sea. U. S. N. Mus. No. 214,300.

FIG. 2

BULIMINUS MEARNSII, new species (Fig. 2)

Shell in general resembling the preceding species, but much smaller, having about six whorls in all, with similar but more delicate sculpture, the suture of the last whorl appressed, the color generally paler, the spire with its sides more flattened; the reflected lip is white, the throat pinkish brown; there is a narrow but distinct and deep umbilical perforation, only partially overshadowed by the reflected pillar lip; height, 25.0; of last whorl, 10.5; of aperture, 14.0; max. diameter, 10.0 mm.

Collected by Lt. Col. E. A. Mearns in the southern part of N'Guaso Nyiro, British East Africa. U. S. N. Mus. No. 214,299.

A section shows that the umbilical perforation expands considerably inside the axis of the last whorl and continues through the axis in the penultimate whorl, though more contracted. The external orifice of the umbilicus is in rare specimens almost covered by the reflected lip, while in *B. [illegible]*, with which it is easily confused, a minute chink is still exposed by the lip; but the axis is more slender than in *B. mearnsii*, though the latter is much the smaller shell.

FIG. 3

LIMICOLARIA CATHARIA, new species (Fig. 3)

Shell slender, thin, polished, smooth, with a very thin yellowish periostracum (which is usually lost), milky white with narrow, more or less undulated, brown axial lines, with much wider interspaces, usually about fifteen or sixteen in number to the whorl; nucleus glassy, of two or three microscopically punctate whorls, rather blunt at the apex; followed by five or six subsequent slightly convex whorls; suture distinct, not deep; surface apt to be pitted by weathering, but normally smooth or very faintly, locally, obsoletely wrinkled; the individuals vary somewhat in stoutness; aperture comparatively small, a thin glaze on the body, outer lip sharp and thin; pillar short, straight, really white, but frequently having a blackish appearance from dirt being included in the narrow axial perforation which is not quite covered by the reflected pillar. Dimensions of two contrasted individuals in millimeters:

Whorls	Height of shell	Of last whorl	Diameter
7½	42.0	26.5	20.0
7½	46.0	28.0	18.5

Collected by Lt. Col. E. A. Mearns on the Kapiti plains, Uganda Railway, British East Africa. U. S. N. Mus. No. 214,301.

A large number of this species was collected, and the peculiar whiteness of the shell, even when not bleached by the sun, is unusual in the group, and hardly obscured by the delicate periostracum.

In general outline the species is not unlike *L. connectens* Martens, of German East Africa, which has, however, a more or less granulose sculpture.

SMITHSONIAN MISCELLANEOUS COLLECTIONS

VOLUME 56 NUMBER 11

DEVELOPMENT OF THE DIGESTIVE CANAL OF THE AMERICAN ALLIGATOR

WITH FIFTEEN PLATES

BY

ALBERT M. REESE

Professor of Zoology, West Virginia University

(PUBLICATION 1946)

CITY OF WASHINGTON

PUBLISHED BY THE SMITHSONIAN INSTITUTION

1910

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

DEVELOPMENT OF THE DIGESTIVE CANAL OF THE AMERICAN ALLIGATOR

By ALBERT M. REESE
Professor of Zoology, West Virginia University

In a previous paper (6) the writer described the general features in the development of the American Alligator; and in other papers special features were taken up in more detail.

In the present paper the development of the enteron is described in detail, but the derivatives of the digestive tract (liver, pancreas, lungs, etc.) are mentioned only incidentally; the development of these latter structures may be described in a later paper.

No detailed description of the histological changes taking place during development has been attempted, though a brief description of the histology is given for each stage discussed.

The material upon which this work was done is the same as that used for the preceding researches. It was collected by the author in central Florida and southern Georgia by means of a grant from the Smithsonian Institution, for which assistance acknowledgment is herewith gratefully made.

Various methods of fixation were employed in preserving the material. In practically all cases the embryos were stained in toto with Borax Carmine and on the slide with Lyon's Blue. Transverse, sagittal, and horizontal sections were cut, their thickness varying from five to thirty microns, depending upon the size of the embryos.

The first indication of the formation of the enteron is seen in the very early embryo shown, from the dorsal aspect, in figure 1. The medullary folds and notochord are evident at this stage, but no mesoblastic somites are to be seen.

A sagittal section of approximately this stage, shown in figure 1A, represents the foregut, *fg*, as a shallow enclosure of the anterior region of the entoderm, while the wide blastopore, *blp*, connects the region of the hindgut with the exterior. No sign of a tail fold being present, there is, of course, no real hindgut. The entoderm, which has the appearance of being thickened because of the fact that the notochord has not yet completely separated from it, is continuous, through the blastopore, with the ectoderm. Posterior to the blas-

topore the primitive streak, *ps*, is seen as a collection of scattered cells between the ectoderm and the entoderm, apparently formed by proliferation from the ventral side of the ectoderm.

A slightly later stage is shown in figure 2, a dorsal view of an embryo with five pairs of mesoblastic somites. A sagittal section of this stage is shown in figure 2A. The foregut is here more inclosed, and the notochord, *nt*, having separated from the entoderm, *en*, is seen as a distinct layer of cells extending from the foregut to the blastopore.

A transverse section through the headfold of this stage is shown in figure 2B. The foregut is seen as a wide cavity, *ent*, depressed dorsally, apparently, by the formation of the medullary groove and the notochord; it is wider laterally than in a dorso-ventral direction, and its walls are made up of about three layers of closely arranged, irregular cells; the wall is somewhat thinner on the dorsal side, just below the notochord.

Figure 3 is a dorsal view of the next stage to be described; about fifteen pairs of somites are present.

Figure 3A is a transverse section through this embryo near the anterior end of the enteron, *ent*, which cavity, cephalad to this region, is bluntly pointed. As seen in the figure the enteron is here wide from side to side, and is depressed dorso-ventrally except for a wide groove in the ventral wall. This groove is lined with rather more closely arranged cells, and marks the region where the mouth will break through at a somewhat later stage. A short distance caudad to this region the groove disappears and the pharynx is reduced to a shallow slit extending almost to the superficial ectoderm on either side; then the slit-like pharynx becomes suddenly reduced in a lateral and increased in a dorso-ventral direction, to assume the outline shown in figures 3B and 3C. At a point about one-third of the length of the embryo from the tip of the head, the enteron opens to the yolk-sac, so that what now may be called the foregut has this considerable extent. There is, however, not the slightest indication of a tail-fold, so that there is no inclosed hindgut at all. As is shown in figure 3D, the neurenteric canal, *nc*, still opens ventrally, though the medullary canal, *mc*, has now no dorsal opening to the exterior. The medullary canal continues for a short distance (about fifteen sections of five microns thickness) posterior to the opening of the neurenteric canal.

Figure 4 is a surface view of the next stage to be described. There are here about twenty pairs of somites, though the exact number cannot be determined. Although not visible externally in the surface view shown, the gill clefts are beginning to form, and the first one opens to the exterior as will be seen in sections of another embryo

of this stage. The mouth has now broken through, putting the wide pharynx into communication with the exterior; probably the mouth opening is formed at about the time of the opening of the first gill cleft.

Figure 4A represents a transverse section through the head of an embryo of the approximate age of the one just described; it passes through both forebrain, *fb*, and hindbrain, *hb;* through the extreme edge of the optic vesicles, *ov*, and through the anterior end of the notochord, *nt*. It is just cephalad to the anterior end of the pharynx and to the hypophysis. The chief purpose in showing this section is to represent the two large head-cavities, *hc*. The origin of these cavities may be discussed at a later time. They are irregularly oval in cross section, and extend in an antero-posterior direction for a distance about equal to their long axis as seen in cross section. The two cavities project towards each other in the middle line, and are almost in contact with the notochord, in the region figured, but they do not fuse at any point. These two head-cavities are the only ones to be seen, in this animal, unless the small evaginations from their walls represent other cavities fused with these. Their walls are thin but distinct, and consist of a single layer of cells. These cells are completely filled with their large, round nuclei, so that the wall has the appearance, under higher magnification than is used in this figure, of a band of closely strung, round beads.

Figure 4B represents the eighteenth section caudad to the one just described. It passes through that region of the enteron, *ph*, which may be called the pre-oral gut, since it lies cephalad to the now open mouth. Owing to the plane of the section the upper angle of the first gill cleft, g^1, is seen on the left, although this would not naturally have been expected in a section through the pre-oral gut. The evagination to form the hypophysis, *p*, is seen against the floor of the forebrain, *fb*. The wall of this region of the enteron is comparatively thin, and consists of not more than two layers of compactly arranged cells with round nuclei.

Figure 4C is about forty sections caudad to the one just described. It passes through the mouth, seen as a vertical opening between the two mandibular arches, *md*. The hyomandibular cleft, g^1, the only one which opens to the exterior in this embryo, is very wide, and may be traced through a number of sections; in this section the opening is seen only on the left. The pharynx, *ph*, is very wide; as it is followed caudad its ventral opening is gradually closed by the approach of the two mandibular folds. The dorsal wall of this region of the pharynx is very thin, consisting of a single layer of flat cells with round nuclei; while the ventral wall, leading through

the mouth and lining the mandibular folds, is composed of two or three layers of compactly arranged cells.

Figure 4D is through a plane sixteen sections caudad to the last. In this region, which is just caudad to the otic vesicles, the pharynx has still its rectangular outline, and its walls are of the same character as in the preceding figure. The posterior edges of the hyomandibular clefts are seen projecting in a ventro-lateral direction, g^1; while dorsal to these are the wider, second pair of clefts, g^2. Where the mandibular folds come together posterior to the mouth, they fuse first at their outer or ventral border, which leaves a deep, narrow groove in the anterior floor of the mouth. As this groove is followed caudad its ventral wall is seen to become much thickened, *tg*, to form the *anlage* of the thyroid gland. In the present section the walls of the groove are just fusing, to cut off the cavity of the gland from the dorsal part of the groove. The next section caudad to this shows the thyroid as a round, compact mass of cells, with a very small lumen, still closely fused with the bottom of the oral groove. The lumen may, in this embryo, be traced for only a few sections, caudad to which the thyroid is seen as a small, solid mass of cells unattached to the oral groove. Close to the sides of the thyroid are seen two large blood vessels, *ar*, the mandibular arches, which unite into the single ventral aorta just caudad to the posterior end of the thyroid. High power drawings of the thyroid just described are shown in figures 4E and 4F.

Figure 4G is about fifty-five sections caudad to the preceding figure, and passes through the middle region of the heart, *ht*. The enteron, *ent*, is cut caudad to the last gill cleft, but it is nearly as large as in the pharyngeal region described above; its walls are of a more even thickness than in the more anterior sections, though there is an area, just below the aorta, where the wall is still but one cell thick. In the ventral wall of this part of the enteron, and, to some extent, in the lateral walls, there seems to be a tendency for the nuclei to become collected toward the side of the wall away from the digestive cavity; this condition cannot be well seen in the figure owing to the amount of reduction in reproduction.

Figure 4H is seventy-nine sections posterior to the last, and passes through the foregut, *ent*, just cephalad to the anterior intestinal portal and caudad to the heart. The outline of the enteron is here almost a vertical slit, and the lining entoderm consists, in its dorsal and lateral regions, of a single layer of columnar epithelium, while in its ventral region, where it adjoins the liver trabeculae, it is made up of several layers of cuboidal or irregular cells. The nuclei in the dorsal and lateral regions of the entoderm are arranged in a very definite layer

at the basal ends of the cells, though an occasional nucleus may be seen near the center of the layer. The mesoderm that extends ventrad from the mesentery, on each side of the entoderm just described, consists of a thick layer of compactly arranged cells. The ventral end of the entodermal wall is fused with the wall of a small cavity, *li*, which may be traced several sections cephalad to this plane. This cavity is a part of the system of hollow liver trabeculae seen as a group of irregular masses of cells ventrad to the enteron at the opening of the anterior intestinal portal. The large blood vessel, *bv*, is the meatus venosus.

Figure 41 is just four sections caudad to the preceding. It passes through the anterior intestinal portal, *aip*. The medial liver trabecula into which the enteron was seen to open, in the preceding figure, now opens ventrally to the yolk-sac as the anterior intestinal portal. A few liver trabeculae are to be seen on either side of the portal, but they show no lumena, and may be traced through only a few sections. The extent of this uninclosed region, the midgut, is very difficult to determine with accuracy, but, at this stage, it comprises about one-half of all the sections of the series. The difficulty is due partly to the unavoidable tearing of the tissues in removing the embryo from the yolk-sac, and partly to the indefiniteness of the posterior intestinal portal, where the walls of the enteron are very thin. As seen in figure 41 the location of the anterior intestinal portal is very distinct.

A short distance caudad to the anterior intestinal portal there is constricted off from the roof of the midgut a narrow diverticulum, figure 4J, *i*, the meaning of which is not apparent; it extends through only ten to fifteen sections, tapering caudad till it disappears. The region of the hindgut, at this stage, is about one-fifth of the entire length of the embryo. Its anterior portion is wide and, as has been said, rather indefinite in outline.

Figure 4K represents a typical section through the midgut region of an embryo of about the age of the one from which the preceding figures were drawn. This and the following figures of this stage were drawn from an embryo in which the posterior region was in better condition than in the embryo from which the other figures of the stage were taken. The mesentery, *ms*, is here of considerable length and continues around the yolk in a layer of diminishing thickness. The epithelium of this region of the enteron consists of a single layer of fairly regular cells, which are columnar in the dorsal region, just beneath the mesentery, and cuboidal or even flattened in regions more distant from the median plane.

Figure 4L, through the region of the hindgut, shows at *i* the completely inclosed intestine; it is a comparatively narrow tube, lined

with columnar epithelium outside of which is a dense layer of mesoblast continuous with the mesentery. In the center of the figure the allantois, *al*, is seen as an irregular cavity, lined with a single layer of columnar or cuboidal cells, and surrounded by a thick mass of loosely arranged, stellate mesoblast cells. The allantois is probably somewhat larger here than in the other embryos used for this stage, in which it was torn away. The tail, *t*, of the embryo is shown at the lower side of the figure, surrounded by the amnion; it is cut in the region of a curve so that the caudal intestine, *i*, is cut longitudinally and has the outline of an elongated ellipse. In this embryo the caudal intestine could be followed to the end of the tail, through several dozen sections; for some distance posterior to the allantois it is extremely narrow, so that its lumen is almost obliterated, and its walls are made up, in any one place, of not more than a dozen cuboidal cells. Towards the posterior end of this region the intestine is considerably enlarged as seen in figure 4L.

Figure 4M passes through the region where both the allantois and the Wolffian ducts open into the hindgut. The union of the allantois and the gut accounts for the elongated outline of the enteron in this section. The openings of the Wolffian ducts, *wdo*, are seen at the lower end of the section of the enteron. The cells lining the Wolffian ducts are smaller than those lining the enteron. In the lower side of the figure are seen the structures of the tail, including the outline of the tiny caudal intestine, *i*, mentioned above. No sign of a cloacal invagination could be made out with certainty.

The next stage to be studied is shown in surface view in figure 5.

Figure 5A represents a section through the head region of this embryo. Owing to the obliquity of the plane of the section the figure is quite asymmetrical. The pharynx, *ph*, is lined with a comparatively thin epithelium and opens, on the left, at two places, one the mouth and the other the second gill cleft, g^2. In the dorsal wall of this cleft, as well as in the corresponding wall of the opposite cleft, is seen a thickening of the epithelium; these thickenings, *ty*, are the rudiments of the thymus gland, whose development may be described in detail in another paper. Compared to the size of the gill clefts the cavity of the pharynx is, at this stage, comparatively small.

Followed caudad the pharynx becomes depressed until, in the region shown in figure 5B, it is a mere narrow slit, *g*, extending transversely across the embryo and opening through the gill clefts to the exterior on each side.

Figure 5C passes through the posterior region of the pharynx, *ph*, the tip of the forebrain, *fb*, the anterior edge of the heart, *ht*, and the curve of the tail, *t*. The chief point of interest in this section is

the thyroid gland, *tg*. It now lies deep in the tissue of the floor of the pharynx, entirely separated from the pharyngeal epithelium. It consists of a compact mass of cells, now showing a bilobed structure in its anterior end, and extending through about twenty-five ten-micron sections. It is solid throughout most of its extent, but, in the section figured, which is near the anterior end, the lobe on the right side shows a small but distinct cavity scarcely visible in the figure.

Caudad to the region just described the pharynx contracts suddenly to form the oesophagus, a narrow, V-shaped slit, which soon divides into an upper and a lower cylindrical tube, figure 5D, *ent*.

Followed caudad the lower of these tubes divides into the two bronchial rudiments, figure 5E, *lu*, which, in the embryo here figured, extend through nearly one hundred sections. In the region shown in figure 5E the three tubes, *oe* and *lu*, lie at the angles of an imaginary equilateral triangle, while in the region of the liver, where the bronchial rudiments end, the tubes lie in the same horizontal plane.

A short distance caudad to the ends of the bronchial rudiments the oesophagus turns suddenly ventrad and becomes much enlarged to form the stomach, figure 5F, *i'*, which may be traced through twenty-five or thirty sections in this series. The epithelium of the stomach is fairly thick, and consists of five or six layers of compact, indistinctly outlined cells with spherical nuclei. Ventrad to the stomach is seen, in figure 5F, a section of the duodenum, *i*, which extends, with gradually diminishing caliber, for twenty-five or thirty sections caudad to the posterior limit of the stomach, where it opens to the yolk-sac and is lost.

The section that cut this embryo in the posterior region of the stomach also passed through the hindgut in the region of the posterior appendages, figure 5G. There the intestine, *i*, is a distinct, cylindrical tube which extends, with not much variation in caliber, and with little variation in position, from this point to the cloaca. Followed cephalad, towards the posterior intestinal portal, it gradually diminishes in caliber, as did the foregut on approaching the anterior intestinal portal. The epithelium consists here of three or four layers of compactly arranged cells, and has about the same appearance as in the oesophagus and duodenum.

Figure 5H represents a section through the cloacal region, *cl*, showing the openings into the cloaca of the Wolffian ducts, *wdo*. Just anterior to these openings the cloaca opens ventrally into a small, anteriorly-projecting pouch, the rudiment of the allantois.

Caudad to the openings of the Wolffian ducts the cloaca extends

ventrad as a narrow, solid tongue of epithelium towards the exterior, figure 51, and fuses with the superficial ectoderm at the caudal end of a prominent ridge that lies in the mid-ventral line between the posterior appendages. In this embryo the cloaca has no actual opening to the exterior; the walls of the part that projects towards the exterior are in close contact, except in the region of the openings of the Wolffian ducts, as is shown in figure 5H.

Owing to the coiling of the end of the long tail the plane of the section, as is seen in figure 51, passes through the posterior end of the embryo no less than four times. In the most posterior of these four sections of the tail, beginning slightly caudad to the section here shown, is seen a small cavity which may be called the post-anal gut, *pag*. It has thick walls, and extends for about thirty-five sections in the series under discussion. Its lumen is very large in its caudal region, figure 51, *pag*, and tapers gradually cephalad until it disappears. Posteriorly the post-anal gut ends quite abruptly not very far from the extreme tip of the tail.

Figure 5J is a composite drawing from reconstructions of the enterons of two embryos of approximately this stage. One of these reconstructions was plotted on paper from a series of transverse sections; the other was made in wax from a series of sagittal sections. For the sake of simplicity the gill clefts are not represented, and the pharynx, mouth, and liver are represented in outline only. For the same reason the lung rudiment of one side only is shown.

The relative size of the pharynx, *ph*, as seen in the figure, is smaller than it is in reality because of the small dorso-ventral diameter (the only one here shown) compared to the lateral diameter. The end of the lung rudiment, *lu*, is slightly enlarged and lies in a plane nearer to the observer than that of the oesophagus, *oe*, though this is not well shown in the figure.

The oesophagus, *oe*, diminishes slightly in caliber for a short distance caudad to the origin of the lungs, then gradually increases in caliber until it suddenly bends to the side (towards the observer) and merges into the wide stomach, *i'*. The stomach, which is irregularly conical in shape, lies in a place slightly nearer the observer than the end of the lung rudiment mentioned above.

Lying to one side of the stomach and duodenum, and extending cephalad beyond the end of the lung rudiment is the liver, *li*, whose outline is only roughly shown here by the broken line. The stomach opens rather abruptly into the duodenum, *d*, which slopes back towards the plane of the oesophagus (away from the observer).

The projection from the side of the duodenum, *pan*, not well figured here, indicates the position of the pancreas, better shown in

the next reconstruction. The duodenum extends only a short distance caudad to this point and then opens, *aip*, to the yolk-sac.

The yolk-stalk, or unclosed region of the enteron, is still of considerable extent, though its exact boundaries are not easy to determine. The distance between the anterior and posterior intestinal portals is approximately shown in the figure under discussion.

The hindgut is cylindrical in cross section and of about the same diameter throughout, except for a slight enlargement in the cloacal region.

The post-anal gut is not shown here; it will be described in connection with the next reconstruction where it is figured.

Figure 6 is a surface view in profile of an embryo of the next stage to be studied. The manus and pes are here well developed, and the general development of the embryo is in considerable advancement over the last stage studied.

Figure 6A represents a reconstruction, from a series of transverse sections, of the enteron of an embryo of about the age of the one shown in figure 6. The outlines of the entire embryo, of the eye, *e*, and of the anterior, *aa*, and posterior, *pa*, appendages are shown by broken lines. Its position being coincident with that of the stomach, liver, and pancreas, the anterior appendage can scarcely be seen. The enteron, including one lung only, for the sake of simplicity, is shaded solid black, while the liver and pancreas, with their ducts, are outlines with unbroken lines. As in the preceding reconstruction no attempt is made to show the gill clefts, and only the dorso-ventral profile of the enteron is shown. Caudad to the pharynx, the enteron being more or less cylindrical in section, this profile gives a good idea of its shape, but in the pharyngeal region, where the lateral diameter is so much greater than the dorso-ventral, the reconstruction gives but a poor idea of the size of that part of the enteron.

The widely-open mouth, *m*, leads, with no line of demarkation, into the pharynx, *ph*, which is of irregular outline and, as has been said, of much greater lateral than dorso-ventral diameter.

The pharynx becomes gradually constricted to form the oesophagus, *oe*, a very long and slender structure, which, as will be seen in cross section, is, at this stage, solid for the greater part of its length. As in the case of the pharynx, the lateral diameter of the oesophagus is generally greater than the dorso-ventral diameter.

From the floor of the caudal part of the pharynx is pushed out the trachea, *ta*. In the reconstruction, especially in the anterior end, the trachea appears several times the diameter of the oesophagus; this is due to the great thickness and indefiniteness of its walls rather than to a greater diameter of its lumen.

At about the position of the line *ta* the trachea divides into the two bronchi (only one shown in the figure), which are somewhat enlarged at the ends to form the lung rudiments, *lu*. While the trachea and bronchi lie ventrad to the oesophagus, the lungs lie laterad and even dorsad to the oesophagus and cardiac end of the stomach. Caudad to the heart and in the region of the anterior appendages, *aa*, the oesophagus suddenly enlarges to form the stomach, *i'*, which has now quite the outline of the typical human stomach.

From the stomach the duodenum, *d*, extends, following a sort of V-shaped course, towards the yolk-stalk, *ys*. In the region of the yolk-stalk it is somewhat enlarged and ends in a blind sac like a caecum. At the side of this sac is seen the opening of the enteron to the yolk-stalk; the anterior and posterior intestinal portals are not distinguishable from each other. From this point the hindgut, *hg*, extends cephalad until it lies laterad to the middle region of the duodenum, then bends through 180° and extends, in an almost straight line, to the cloaca, *cl*, lying in the region of the posterior appendage, *pa*.

The allantois, *al*, extends cephalad for some distance from the floor of the cloaca. Some distance caudad to the cloaca, near the end of the much coiled tail, is seen the post-anal gut, *pag*. This structure as has been noted above, is quite distinct from the other parts of the enteron. It is of elongated, pyriform outline, with the pointed end extending cephalad.

In the narrow space between the stomach and the duodenum is the elongated pancreas, *pan*, opening by two or more short ducts into the duodenum.

The liver, *li*, in the figure under discussion, has about twice the area of the stomach. It extends caudad and dorsal about the same distance as the latter organ, but it extends ventrad and cephalad far beyond the boundaries of the stomach.

Extending along the ventral border of the liver is a long narrow duct, apparently the bile duct, *bd*. It connects, caudally, with the anterior end of the pancreas, while at its other extremity, near the antero-ventral corner of the liver; it ends blindly.

The transverse sections now to be described have been selected from the series from which the reconstruction, just described, was made.

Figure 6B represents a typical section through the pharynx. Its plane is approximately shown by the line 400 of figure 6A though the plane apparently does not cut the eye, *e*. The pharynx, *ph*, has here the outline of an irregular V. Its walls, except at the outer

angles of the clefts, g^1, are composed of but a single layer of cells. In the dorsal wall these cells are flattened, while in the ventral wall they are more rounded. This difference in the shape of the cells accounts for the slightly greater thickness of the floor over that of the roof of the pharynx. The gill clefts no longer communicate with the exterior.

Figure 6C represents the caudal half of the embryo in the plane 475 of figure 6A. The section of the pharynx, *ph*, is here crescentic in outline, and the pharyngeal walls, especially the floor, are somewhat thicker than in the more anterior section just described. Lying a short distance dorsad to the pharynx are seen two small, thick-walled openings, *ty;* these are the rudiments of the thymus glands. They are here quite distinct from the enteron, and may be traced through a large number of sections, being in some regions solid and of a smaller diameter than in the present section.

Figure 6D is in the region of the line 500 in figure 6A. The thymus rudiments, *ty*, have about the same appearance as in the preceding figure, except that they are somewhat larger. The pharynx, *ph*, is much smaller than in the last section, and though somewhat crescentic in outline, its convex side is dorsal instead of ventral in position. The pharyngeal walls are here thicker, and consist of two or three layers of cells, instead of the single layer of more anterior sections.

In the median plane the floor of the pharynx is pushed down, as a solid tongue of cells, *gs*, the anterior edge of the glottis. Ventrad and laterad to the glottis a crescentic condensation of mesoblast represents the beginning of the laryngeal cartilages, *la*.

Two or three sections caudad to the one just described, the two layers of which the tongue of cells from the floor of the pharynx is composed separate slightly at the bottom to form a small cavity, the trachea, *ta;* this condition is shown in figure 6E, which represents part of a section through the plane 532 of figure 6A.

The oesophagus, *oe*, is here a solid, crescentic mass of cells, the lumen being completely obliterated. The dorsal part of the tongue of cells, mentioned above, connects the ventral side of the oesophagus with the trachea, like a sort of mesentery. Above the oesophagus, on either side, is the thymus rudiment, *ty*, in this section practically a solid mass of cells instead of a tube. The epithelium of the trachea here consists of three or four layers of compactly arranged cells; this epithelium is surrounded by a dense mass of mesoblast which is responsible for the greater thickness of the trachea as seen in figure 6A. As has been said, the oesophagus here has no lumen, and when examined under high magnification its walls are found to be com-

pletely fused, not merely in close contact. The same is true of the tongue of cells between the oesophagus and trachea. Two or three sections caudad to the one under discussion this tongue of cells loses its connection with the trachea, and the latter structure is entirely independent of the oesophagus.

The solid condition of the oesophagus continues through about fifty sections of this series, the horns of the crescent gradually shortening until only the central part remains as the hollow cylinder seen in figure 6F, *oe,* which is a section through plane 650 of figure 6A. From about this point to its opening into the stomach the oesophagus has essentially the same structure. Its epithelium is of the simple columnar type, the cells being long, with generally basally located nuclei.

In the section under discussion the trachea, *ta,* is of about the same size as the oesophagus, but its epithelium is thicker and consists of two or three layers of cells. The trachea extends, as a separate and distinct structure, through about one hundred and fifteen sections, and then, at a point four or five sections caudad to the present section, it divides suddenly into the two bronchial tubes. Each bronchus, like the trachea, is lined with an epithelium of three or four layers of cells; but the epithelium is surrounded by a thin layer of much condensed mesoblast. The bronchi continue caudad, with slightly increasing caliber, through about fifty sections, when they suddenly enlarge to form the lungs. As seen in figure 6a the lungs are irregularly conical in outline and lie on either side of the posterior end of the oesophagus.

Figure 6G is a section through the plane 750 of figure 6A. The oesophagus, *oe,* is seen as a small, circular opening between two much larger openings, the lungs, *lu.* The epithelium of the oesophagus is the same here as in the more anterior regions described above; that of the lung rudiments is very variable in thickness, even in different parts of the same section, being in some places composed of a single layer of cuboidal or even flattened cells, in other places consisting of four or five layers of cells (not well shown in the figure). Surrounding the epithelium of the lung rudiments is a thin layer of quite dense mesoblastic tissue. A fairly well defined mesentery, *ms,* is now present in this region.

Filling the greater part of the body cavity, below the oesophagus and lung rudiments, is the liver, *li;* and ventrad to the liver the section passes through a loop of the duodenum, *d.*

The epithelium of the duodenum consists of four or five layers of compactly arranged cells, near the center of an oval mass of fairly dense mesoblast. In a lateral projection of this mass of mesoblast

lies a small, circular opening, the bile duct, *bd*. Its epithelium consists of a single layer of columnar cells. In more anterior sections the bile duct is larger in cross section, being about one-half the diameter of the oesophagus. As has been said it ends blindly at a point a short distance anterior to the antero-ventral edge of the liver. A few sections caudad to the one under discussion the bile duct connects with the liver, figure 6A, *bd'*; and some distance caudad to this the duct opens, *bd''*, into the duodenum so close to the opening, *pan'*, of the pancreas that it is difficult to determine whether the latter organ has a separate opening into the duodenum or opens into the bile duct.

At some distance ventrad to the structures just described the intestine is cut, by the plane of the section, in two places, *i*. The more dorsal of these is inclosed and has, under this magnification, the same appearance as the duodenum, *d*; a higher magnification, however, shows that its epithelium consists of a single layer of tall, rather clear, columnar cells. The more ventral of the two sections, above mentioned, which is continuous with the dorsal section a very short distance caudad to this point, is in the region that opens to the yolk—in fact a number of yolk-granules, *y*, may be seen in the opening. The epithelium of this part of the intestine consists of a single layer of clear, columnar cells, which, around the borders of the opening, are thrown into numerous folds and are almost of goblet form.

Figure 6H represents a section through the plane 820 of figure 6A. The section is caudad to one lung and cuts the extreme tip of the other, *lu*. The liver, *li*, and pancreas, *pan*, are seen at the side of the stomach, *i'*, here cut through its greatest transverse diameter. The epithelium of the stomach varies somewhat in thickness and consists of two or three layers of cells, the variation in thickness being due to a variation in the length of the cells rather than to a variation in the number of layers.

Ventrad to the stomach the intestine, *i*, is cut in three places, of which the most dorsal section is the largest. The epithelium of these intestinal sections, especially the lower two, consists of usually a single layer of columnar cells which are clearer than those of the stomach. A fairly thin mesentery, *ms*, supports this region of the intestine.

In the region of the posterior appendages, *pa*, the section passes through the hindgut, *hg*, and allantois, *al*. The former is of about the same size as the more anterior sections of the intestine, but its epithelium is less clear and is composed of two or more layers of cells. The allantois is cut near its opening into the hindgut; its walls

are thin, the epithelium consisting of but a single layer of more or less flattened cells.

Figure 7 represents a reconstruction of the enteron of an embryo of 42 mm. crown-rump length. Because of the body flexure and large size of the embryo the head was amputated, in the plane *a-b*, and cut sagitally, while the body was cut transversely in the direction shown by the section planes. In the present figure the outline of the embryo, including the eye, appendages, and umbilical stalk, is shown by fine dotted lines; the outlines of the lungs and liver are shown by heavier, broken lines; while the outlines of the enteron proper and the trachea are shown in solid lines, filled in which fine stippling. For the sake of simplicity only one lung and one bronchus are shown.

Since the head has now quite a reptilian form, the oral cavity, *m*, has more or less of the adult outline. A transverse groove near the anterior end of the lower jaw marks off the tongue, *tn;* and the rudiments of teeth are seen but not shown in the figure because of the low magnification used.

The pharynx, *ph*, is a very extensive cavity that is sharply separated from the mouth by a prominent transverse fold of skin, the velum palitum, *vp*, just in front of the posterior nares, *pn*, and by a less marked fold from the base of the tongue; it is these two valves that enable the adult alligator to open its mouth under the surface without getting water into the lungs. The mouth and pharynx are lined at this stage with a thin, stratified epithelium, which consists of a basal layer of rather tall columnar cells and one or two superficial layers of flattened cells. The pharyngeal epithelium is rather thicker than that of the oral cavity,

In the embryo from which this reconstruction was made the pharynx was in direct communication with neither the oesophagus nor the trachea, though the separation in each case was by a mere membrane. The trachea, *ta*, opens, except for this membrane, into the pharynx a short distance back of the transverse, dorsal and ventral folds mentioned above, and almost directly ventrad to the posterior nares. The anterior end of the oesophagus, *oe*, is in contact with the extreme postero-ventral wall of the pharynx.

The trachea, which is already surrounded by distinct cartilaginous rings, is long, and of about the same diameter throughout. In the region of the anterior appendage, at the point marked *X*, it divides into the two very short bronchi, which almost immediately open into the lungs, *lu*. The lungs, whose structure will be shown in the sections of this stage, are large, irregular bodies, extending about equal distances cephalad and caudad to their openings into the

bronchi. The caudal ends of the lungs overlap the cephalic end of the liver, *li.*

The oesophagus, *oe,* is large, and is laterally compressed so that its dorso-ventral diameter, the one shown in the present figure, is two or three times as great as its lateral diameter. This gives the impression, in the reconstruction, that the oesophagus is nearly as large as the stomach.

As has been said, the oesophagus does not open directly into the pharynx, but is separated from it by a membrane which consists of the flattened epithelial layers of both cavities separated by a thin layer of mesoblast. This partition between the pharynx and the oesophagus is not a mere fold of mucous membrane, but is a complete, though thin, wall, easily seen in the series of sagittal sections from which this region of the embryo was drawn. The anterior end of the oesophagus is suddenly constricted so that the actual opening closed by this partition is not large.

Followed caudad the dorso-ventral diameter of the oesophagus varies somewhat, as does the lateral diameter, but it remains large throughout and opens into the stomach with no sharp line of demarkation. The character of the epithelium of the enteron caudad to the pharynx will be discussed in connection with the sections to be described below.

The stomach, *i'*, is very different in outline from what was seen in the last stage described, figure 6A. Instead of having approximately the form of the typical mammalian stomach it is now so elongated that the opening into the duodenum, the pylorus, *py,* seems to be nearer the anterior than the posterior end. While the position of the pylorus is very distinct it is difficult to distinguish the line of demarkation between the stomach and the oesophagus.

The extreme caudal region of the stomach is enlarged to form a blind sac, representing the gizzard, *gz.* A slight enlargement in the region of the pylorus may represent the glandular region of the adult stomach. The stomach opens, in a rather curious way, into the side of the duodenum, *d,* the anterior end of the latter structure having the appearance of a sort of caecum, to be seen in the next stage of development.

The duodenum, *d,* makes a U-shaped bend at the side of the stomach, and then, in the region of the caudal edge of the gizzard, *gz,* dips suddenly ventrad and caudad towards the umbilical cord, *u,* where it apparently ends blindly, though this appearance is probably due to an artifact in the embryo from which the reconstruction was made. It is likely that, in removing the embryo from the yolk, the connection between the two loops, *i,* of the intestine was broken.

The ascending intestinal loop is of slightly less caliber than the descending loop above mentioned; it passes dorsal and cephalad to the posterior border of the gizzard where its lumen is continuous, for a short distance, with that of the descending loop above described. This unusual condition is probably abnormal, but owing to lack of material only one series of this stage was studied.

At the dorso-caudal angle of the gizzard the small intestine, *i*, opens into the ventral side of a larger tube which may be called the large intestine, *il*. The blind end of the large intestine, cephalad to the opening of the small intestine, projects forward, dorsal to the gizzard, as a sort of caecum, *ce*, though this structure is generally stated to be wanting in the crocodilia, and is not seen in the next stage.

From the caecum the large intestine passes in a ventro-caudal direction, with gradually decreasing caliber, to the cloaca, from whose anterior wall the intromittent organ, *io*, projects.

From the ventral wall of the large intestine, at a point about one-third the distance from the cloaca to the caecum, projects ventrad and cephalad the stalk of the allantois, *al*. Owing to its thin walls and small lumen the allantois was traced only a short distance into the umbilical stalk.

The profile of the liver, *li*, has, at this stage, about the same area and even outline as that of the lung. It lies, of course, on both sides of the enteron proper, and overlaps, anteriorly, as has been said, the posterior end of the lung.

Figure 7A represents a section through the plane 305 of figure 7. A considerable advance in the general development of the organs is seen over the last stage studied. The spinal column is well outlined in cartilage, and the ribs are cut at various places, *r*. In the body wall a considerable differentiation of muscular tissue has taken place, but it is only faintly shown in this series of figures. The scales, especially along the mid-dorsal line, are shown as an area of less closely dotted tissue.

The lungs, *lu*, cut here through their anterior ends, are large, but do not nearly fill the cavities, *bc*, in which they lie; they have the sacculated appearance characteristic of embryonic lung tissue.

The oesophagus, *oe*, is cut through about its middle region, where its caliber is greatest. As was said above, its dorso-ventral diameter is more than twice its lateral diameter, caused partly by the oblique angle at which it was cut. Its wall, figure 7H, is very thin and exhibits a dense layer of mesoblastic tissue, in which circular and longitudinal muscle layers are beginning to differentiate. It is lined by an epithelium which here consists of a single layer of columnar

or cuboidal cells with large nuclei. On the ventral side, where the oesophageal wall is in contact with that of the trachea the epithelium is somewhat thickened by an increase in the number of cell layers. With the low magnification used these details could not, of course, be shown.

The trachea, *ta*, is of much smaller caliber than the oesophagus, especially in its dorso-ventral diameter. While its epithelial lining is not yet appreciably different from that of the oesophagus, its connective tissue wall is much thicker and shows numerous condensations, the rudiments of the cartilaginous rings. In the region represented by this figure the connective tissue layers of the trachea and oesophagus are continuous with each other, but cephalad and caudad to this point they are distinct, though sometimes in contact. Several large blood vessels, *bv*, on each side of the oesophagus probably represent the carotids and jugulars, but they were not worked out to determine with certainty which they were.

Eighty-five sections (figure 7, *X*) caudad to the one under discussion the trachea divides into the two bronchi. These bronchi gradually separate from each other until, at the point at which they open into the lungs, about eighty sections caudad to their point of separation, they lie on either side of the ventral third of the oesophagus.

Figure 7B represents a section through the plane 480 of figure 7. The section is just cephalad to the heart, and passes through the caudal third of the lungs, *lu*, which have the same appearance as in the preceding figure; also through the extreme cephalic end of the liver, *li*. The lungs here much more nearly fill the body cavity than in the preceding figure. The section being caudad to their openings into the lungs the bronchi do not, of course, show.

The oesophagus, *oe*, is here of much less diameter than in the preceding figure, but is still laterally compressed. Its wall is somewhat thicker than in the more cephalic region, the increase being mainly due to the greater thickness of the connective tissue layer, though the epithelium is also slightly thicker because of an increase in the length of the lining cells. Instead of lying almost entirely ventrad to the lungs, as in the preceding figure, the oesophagus here lies directly between them.

Figure 7C represents a section through the plane 627 of figure 7. The plane of the section passes through the opening of the stomach, *i'*, into the duodenum, *d*. The cross section of the stomach is somewhat larger than that of the oesophagus, but it differs from the more anterior region mainly in the character of its walls. These are much thicker than in the oesophagus; in the mesoblast which

forms the greater part of their thickness, muscle fibers are beginning to differentiate. The epithelial layer also is thicker than in the oesophagus; it consists of tall columnar cells that, at places, are thrown into small folds, figure 7I. These folds, even under the low magnification used, are more evident than is shown in the present figure. The pylorus, *py*, is wide and, as has been noted in connection with figure 7, is situated far cephalad to the caudal end of the stomach. It opens into the side rather than into the end of the duodenum, which projects cephalad as a short blind pouch, *d*. The stomach and duodenum, in this section, are almost completely surrounded by the liver, *li*.

Figure 7D represents a section through the plane 680 of figure 7. The stomach, *v*, which is cut through its middle region, is somewhat larger than in the preceding figures, though its walls have about the same character. Its outer walls are continuous, to a considerable extent, with the tissue of the surrounding body wall, especially in the region just caudad to the plane of the present section.

The duodenum, being cut through a double loop (see figure 7), is seen in two places, dorsally where it is cut through the edge of one loop, and ventrally where it is cut square across. In both sections the structure is the same, as might be expected, figure 7J. The surrounding mesoblast is differentiated into muscle fibers, figure 7J, *ml*, which form a fairly distinct layer; inside of this layer is a tall columnar epithelium, *ep'*, which is thrown into prominent folds. A thin layer of mesoblast, probably the submucosa, *sl*, lies beneath the epithelium and projects up into the folds. About ten or twelve folds are seen in any one section; only the larger ones are well seen in figure 7D.

Figure 7E shows a section through the plane 770 of figure 7. It is in the region of the umbilicus, *u*, and the extreme caudal end of the stomach which has been called the gizzard, *gz*. The small size of the gizzard is due to its being cut near its caudal margin. The enteron is here cut in no less than seven places: the reason for this will be evident on examination of the plane of the section as shown in figure 7. Dorsal to the gizzard the section cuts the so-called caecum, *cc*, a little nearer its anterior end than is shown in figure 7. The duodenum, *d*, is cut at five points, and has about the same structure as in the preceding figure. The character of the duodenal loops that causes the rather curious appearance of the present figure will be readily understood by reference to figure 7, though the reconstruction is not mathematically accurate. The ventral projection of the lower loops of the duodenum into the umbilicus is seen both in the present figure and in the reconstruction. The loop of

the duodenum that, in the sections, is seen to lie directly ventrad to the gizzard, in the reconstruction is shown too much to the side of the latter organ. The descending loops of the duodenum are cut in such a way that the surrounding mesoblast forms a continuous mass of tissue.

Figure 7F represents a section through the plane 901 of figure 7. The section passes through the kidneys, *k*, the edge of one posterior appendage, *pa*, the large intestine, *il*, and two regions of the small intestine, *i*.

The large intestine is here a thick walled, cylindrical structure, *il*, hanging from a thin mesentery, *ms*, in the much reduced body cavity. The layers of its wall are much more fully differentiated than in the more anterior regions of the enteron. The epithelium is here stratified instead of simple columnar, and the folds into which it is thrown are broader and less numerous than in the duodenum above described.

Ventrad to the large intestine, and almost in contact with it, is seen the allantois, *al*, whose general outline was noted in connection with figure 7. It is an irregular structure, consisting of a very thin outer layer of mesoderm, lined with a single layer of flattened epithelial cells.

Lying at a considerable distance ventrad to the main body of the section, are seen the two sections of the small intestine, *i*, surrounded by irregular strands of tissue from the umbilicus. The structure of these two intestinal loops is about the same as in the more anterior region described above.

Figure 7G, the last of this series, represents a section through the cloaca, caudad to the urinary openings, in the plane 1060 of figure 7. The epithelium of the cloaca is, of course, simply a continuation of that of the surface of the body, somewhat thickened, perhaps, in the deeper regions.

The intromittent organ, *io*, which projects cephalad from the wall of the cloaca, is here seen as a three-pointed body of considerable size, projecting ventrally from the body.

Figure 8 shows in outline the enteron, from the ventral aspect, of an embryo of 20 cm. total length, or at about the time of hatching. The drawing was made from a dissection and, for the sake of simplicity, only the enteron, respiratory organs, heart, and thymus are shown. The jaw is cut through on the left side and is turned over to the right, thus bringing into view the roof of the mouth, *m*, and the dorsal side of the tongue, *tn*. At the same time the pharynx, *ph*, and the wide anterior end of the oesophagus, *oe*, are cut open, exposing the glottis, *gs*, and vocal cords, *vc*.

The lungs, *lu*, and trachea, *ta*, which are now fully formed, are dissected loose and drawn over to the right side of the animal, together with the heart, *ht*, and the thymus, *ty;* only one side of the thymus is shown, the other half being hidden by the trachea.

The mouth has reached nearly the outline of the adult. The lips are formed and, in the anterior part of the lower jaw, four tooth rudiments, *to*, are externally visible. The mucous membrane of the roof of the mouth, *m*, is covered with rounded papillae, easily seen with a lens but not shown in the figure. The tongue, *tn*, is fully formed, and is free anteriorly and laterally to about the extent that is seen in the adult; the papillae with which it is covered are not so prominent as those seen on the roof of the mouth. At the base of the tongue is the prominent transverse fold, noted in connection with figure 7, that meets above the velum palitinum, not shown here but shown in figure 7. Caudad to these folds is seen the glottis, *gs*, a triangular opening with the vocal cords, *vc*, at its base.

The mucosa of the inside of the pharynx and the anterior end of the oesophagus, exposed by the dissection, is thrown into numerous longitudinal folds, not shown in the figure; these well-marked folds extend throughout the length of the oesophagus.

The oesophagus, *oe*, tapers gradually from the wide pharynx, *ph*, and then continues as a cylindrical tube of uniform diameter to the right side of the anterior end of the stomach, where it opens into the latter organ. Its walls are thick, and its lumen is almost obliterated by the longitudinal folds of the mucosa, mentioned above.

The stomach, *i'*, is oval in outline, though somewhat flattened laterally; it is depressed, dorso-ventrally, to a little more than half the lateral diameter. As has been said, the oesophagus enters its right anterior border; the pylorus is on the right side, 3 or 4 mm. caudad to the oesophageal opening. The wall of the stomach is comparatively thin except in the region of the oesophageal and pyloric apertures, and at a point, opposite these apertures, on the left side. At the latter point is an oval or disc-shaped area that is several times as thick as the surrounding wall; it probably represents the gizzard structure of the adult. The thickening mentioned in the region of the two apertures seems to be mainly due to a wrinkling of the mucosa which, in other parts of the stomach, is nearly smooth, so far as can be seen with the naked eye. A sphincter thickening around the oesophageal and, to some extent, around the pyloric aperture, causes each of these structures to project into the stomach like an ileo-caecal valve.

The pylorus, *py*, opens into a small, pointed, thin-walled diverticulum, *di*, and, at the same time, into the duodenum, *d*. The diver-

ticulum noted, also, in connection with figure 7, has relatively thick, wrinkled walls; its significance is not known to the writer. From this diverticulum the duodenum, *d*, leads caudad and laterad for a short distance as a narrow tube, then suddenly expands into the widest part of the entire intestine. Into this wide part of the duodenum, 3 or 4 mm. from the pylorus, opens the bile duct, *bd*. The bile sac, *bs*, is an elongated oval body with thin walls, lying to the right of the pylorus, its connection with the liver was not seen.

Lying between the anterior end of the duodenum and the posterior end of the stomach, and extending caudad for 10 to 15 mm., in the median plane of the animal is the pancreas, *pan*. It is a long narrow body of a whitish color; its duct or ducts could not be determined by dissection. The duodenum extends caudad, with gradually diminishing caliber, from the enlarged region mentioned above. About 10 to 15 mm. caudad to the stomach it makes a sort of double loop to the right, a wide loop, *lp*, and a close one, *lp'*, nearer the median plane. From the latter loop the intestine extends straight to the left, for a distance of about 10 mm., where it makes a small loop cephalad, lp^2, and then opens to the yolk-sac, *y*. The yolk-sac is shown here simply as an irregular piece of tissue, the yolk having been removed.

The anterior intestinal portal, *aip*, and posterior intestinal portal, *pip*, are in close proximity with each other.

From the posterior intestinal portal the intestine extends straight cephalad to the posterior end of the stomach, dorsal to which it forms a double loop, a wider one, lp^3, and a narrow one, lp^4. From the latter loop, lp^4, the intestine extends straight caudad, parallel and near to the straight region leading from the posterior intestinal portal, until it reaches the region of the loop lp^2, dorsal to which it forms a small loop, lp^5. From loop lp^5 the intestine, which is here of very small caliber, extends caudad for about 10 mm., where it forms another indistinctly double loop, lp^6.

From loop lp^6 the large intestine, *il*, extends, with gradually increasing caliber, to the cloaca, *cl*, a distance of 10 to 15 mm.

Except in the enlarged region near the pylorus the lumen of the intestine is almost obliterated by the folding of its thick walls, so that little or nothing can be told of its lining with the naked eye.

A distinct mesentery holds the loops of the intestine in position and binds the entire enteron close to the dorsal body wall. Because of the lack of properly fixed tissue no sections of the enteron of this stage were made.

REFERENCES

1. BRONN, H. G.: Klassen des Thier-Reichs. (Vols. on reptiles.) 1890.
2. CHAFFANJON, V.: Observations sur Alligator mississippiensis (Tractus intestinalis und Mesenterium). Ann. Soc. Linn. Lyon, vol. 28, p. 83 ff., 1881.
3. EISLER, P.: Zur Kentniss der Histologie des Alligatormagens. Archiv f. Mikr. Anat., vol. 34, pp. 1-10, 1889.
4. HERTWIG, O.: Comparative Embryology of Vertebrates. Especially vol. 2, pp. 1-241, 1906.
5. REESE, A. M.: The Nasal Passages of the Florida Alligator. Proc. Acad. Nat. Sc. Phila., 1901.
6. REESE, A. M.: The Development of the American Alligator. Smith. Misc. Coll., vol. 51, No. 1791, pp. 1-66, 1908.

DESCRIPTION OF FIGURES 1-8, PLATES 1-15

The surface views were drawn, under the author's direction, by Miss C. M. Reese. The first two of these views were copied, by permission, from S. F. Clarke; the others were drawn from the specimens themselves.

All of the figures of any one stage are given the same number, followed by distinguishing letters, so that it is possible to tell at a glance what figures belong together.

All of the figures except those from Clarke were drawn under a camera lucida.

Figure 1. A surface view of an embryo, from the dorsal aspect, at the beginning of the formation of the enteron.

Figure 1A. A sagittal section of an embryo of approximately the age of the one shown in figure 1. × 43.

Figure 2. A dorsal view of an embryo with five pairs of mesoblastic somites.

Figure 2A. A sagittal section of an embryo of the stage shown in figure 2. × 43.

Figure 2B. A transverse section through the headfold of an embryo of the stage shown in figure 2. × 43.

Figure 3. A dorsal view of an embryo with about fifteen pairs of somites. × 20.

Figures 3A-3D. A series of transverse sections through an embryo of the stage of the one shown in figure 3. × 43.

Figure 4. A surface view of an embryo with about twenty pairs of somites. × (about) 15.

Figures 4A-4D. A series of transverse sections through the anterior end of an embryo of the approximate age of the one shown in figure 4. × 20.

Figures 4E and 4F. Two transverse sections through the thyroid gland of this stage; more highly magnified. × 102.

Figures 4G-4M. A series of transverse sections caudad to the preceding. Figure 4H, × 43; other figures, × 20.

Figure 5. A surface view, in profile, of an embryo at the time of the origin of the limbs. × (about) 5.

Figures 5A-5I. A series of transverse sections through an embryo of the age shown in figure 5. × 7.

Figure 5J. A composite drawing of reconstructions of the enterons of two embryos of the age of the one shown in figure 5. One reconstruction was in wax, from sagittal sections, the other was a plotted reconstruction from transverse sections. × 14.

Figure 6. A surface view, in profile, of an embryo with well developed manus and pes. × (about) 5.

Figure 6A. A reconstruction, plotted from transverse sections, of the enteron of an embryo of about the age of the one shown in figure 6. × 14.

Figures 6B-6H. Part of a series of transverse sections from which the preceding reconstruction was made. × 7.

Figure 7. A reconstruction of the enteron of an embryo of 42 mm. crown-rump length.

Figures 7A-7G. A part of the series of transverse sections from which the preceding reconstruction was made. × 7.

Figure 7H. A high power drawing of a portion of the wall of the oesophagus in the region of figure 7A. × 190.

Figure 7I. A high power drawing of a portion of the wall of the stomach in the region of figure 7C.

Figure 7J. A high power drawing of a portion of the wall of the duodenum in the region of figure 7D.

Figure 8. An outline drawing, from the ventral aspect, of the enteron of an embryo of 20 cm. length, at about the time of hatching; made from a dissection. × 1.

LETTERING FOR ALL FIGURES

a, head-fold of amnion.
aa, anterior appendage.
ac, anterior cardinal vein.
aip, anterior intestinal portal.
al, allantois.
an, anterior nares.
ao, aorta.
ar, aortic arch.
au, auricle.
b, bulbus arteriosus.
bc, body cavity.
bd, bile duct.
bd', opening of bile duct to liver.
bd'', opening of bile duct to duodenum.
blp, blastopore.
bp, basilar plate.
bs, bile-sac.
bv, blood vessel.
c, centrum of vertebra.
ca, caudal artery.
ce, caecum.
ch, cerebral hemisphere.
cl, cloaca.
cm, circular muscle layer.
cn, cranial nerve.
cp, posterior choroid plexus.
cv, cardinal vein.
d, duodenum.
dc, ductus Cuvieri.
di, diverticulum of stomach.
e, eye.
ec, ectoderm.
ec', thickening of ectoderm.
en, entoderm.
en', endocardium.
ent, enteron.
ep, epidermal layer of ectoderm.
ep', epithelium.
epi, pineal body.
cs, embryonic shield.
f, fronto-nasal process.
fb, forebrain.
fg, foregut.
g^{1-5}, gill clefts.
gf^{1-6}, gill folds.
gl, glomerulus.
h, head-fold.
gs, glottis.
gz, gizzard.
hb, hindbrain.
hc, head cavity.
hg, hindgut.
ht, heart.
i, intestine.
i', stomach.
il, large intestine.
in, infundibulum.
io, intromittent organ.
ir, iris.
it, iter.
k, kidney.
la, larynx.
li, liver.
lm, longitudinal muscle layer.
ln, lens.
lp, *lp'*, etc., loops of intestine.
lu, lungs.
lv, lens vesicle.
m, mouth.
ma, manus.
mb, midbrain.
mc, medullary canal.
me', tip end of medullary canal.
md., mandibular folds.
mes, mesoderm.
mes', myocardium.
mf, medullary fold.
mg, medullary groove.
mk, Meckel's cartilage.

ml, muscle layer.
mp, muscle plate.
ms, mesentery.
mv, meatus venosus.
mx, maxillary fold.
myc, myocoel.
n, nasal cavity.
na, neural arch of vertebra.
nc, neurenteric canal.
nl, nervous layer of ectoderm.
nt, notochord.
o, ear vesicle.
oc, optic cup.
oe, oesophagus.
on, optic nerve.
os, optic stalk.
ov, optic vesicle.
p, pituitary body.
pa, posterior appendage.
pag, post-anal gut.
pan, pancreas.
pan', opening of pancreas.
pc, posterior cardinal vein.
pe, pes.
pg, primitive groove.
ph, pharynx.
pip, posterior intestinal portal.
pl, pelvis.
pn, posterior nares.
pr, pericardial cavity.
ps, primitive streak.
pt, pecten.
py, pylorus.
r, rib.
rt, retina.
s, somites.
sc, spinal cord.
se, spenethmoid cartilage.
sg, spinal ganglion.
sl, submucosa.
sm, splanchnic mesoblast.
sn spinal nerve.
so, somatic mesoblast.
st, stomodaeum.
sy, sympathetic nervous system.
t, tail.
ta, trachea.
tg, thyroid gland.
tn, tongue.
to, tooth anlage.
tr, trunchus arteriosus.
tv, *tv'*, third ventricle of brain.
ty, thymus gland.
u, umbilical stalk.
v', *v''*, *v'''*, first, second, and third cerebral vesicles.
va, vascular area.
vc, vocal cords.
vm, vitelline membrane.
vn, ventricle of heart.
vp, velum palitum.
vv, vitelline blood vessels.
wd, Wolffian duct.
wdo, opening of Wolffian duct.
wr, Wolffian ridge.
wt, Wolffian tubule.
x, point of origin of bronchi.
y, yolk.
ys, yolk-stalk.

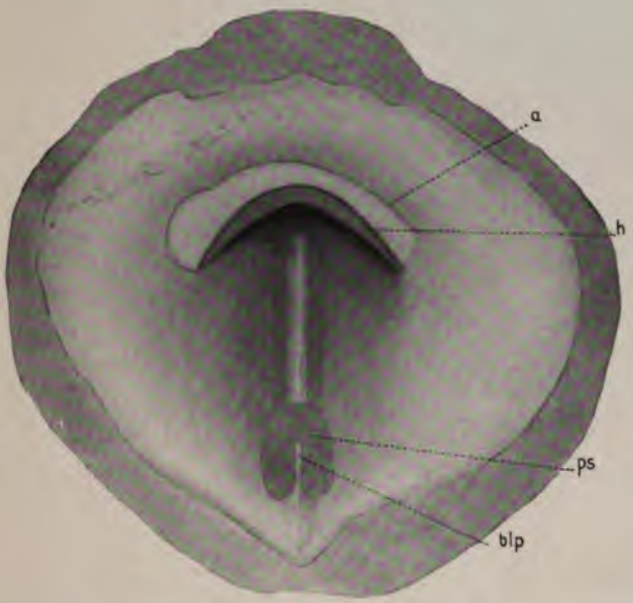


FIG. 1.

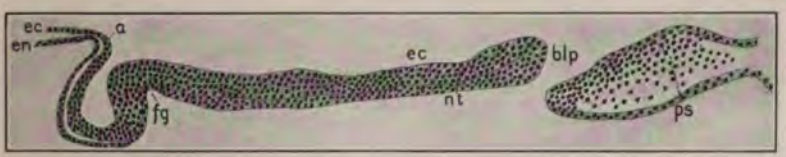


FIG. 1A.

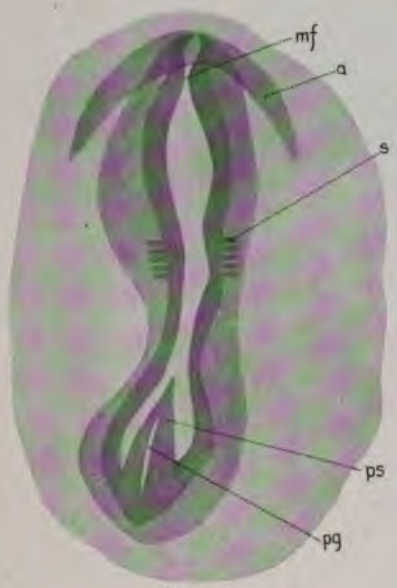


FIG. 2.

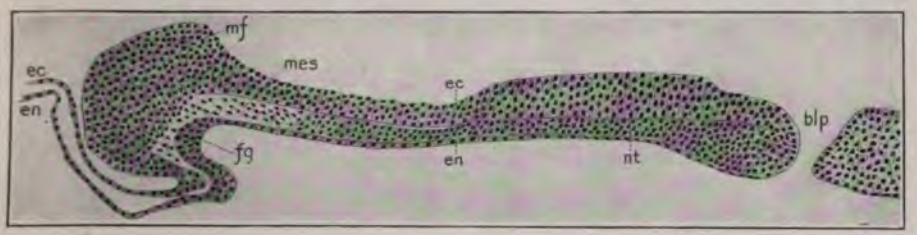


FIG. 2A.

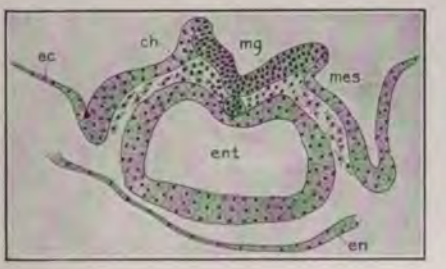


FIG. 2B.

Digitized by the Internet Archive
in 2010 with funding from
University of Toronto

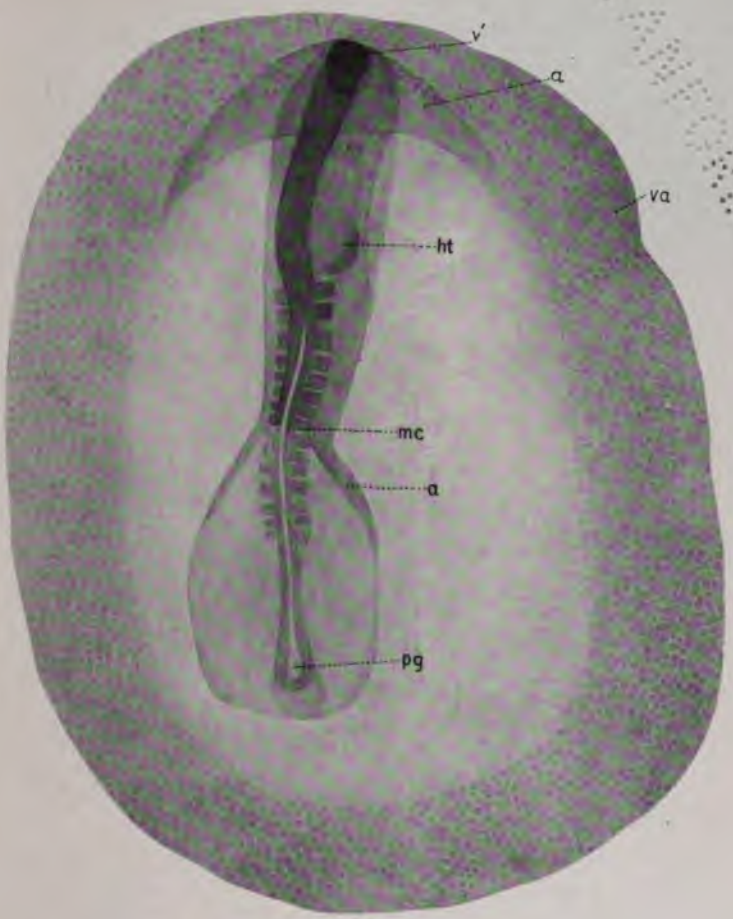


FIG. 3.

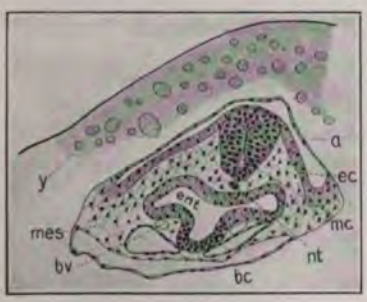


FIG. 3A.

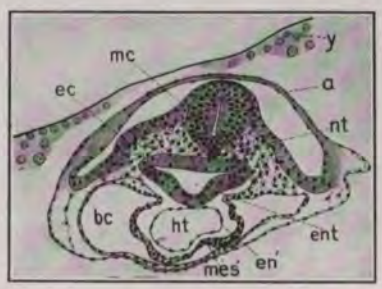


FIG. 3B.

Stanford Libraries

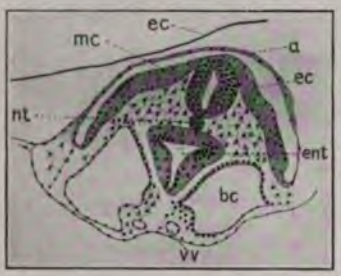


FIG. 3C.

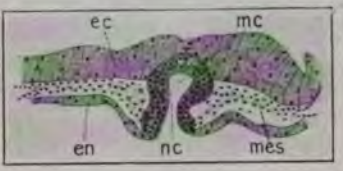


FIG. 3D.

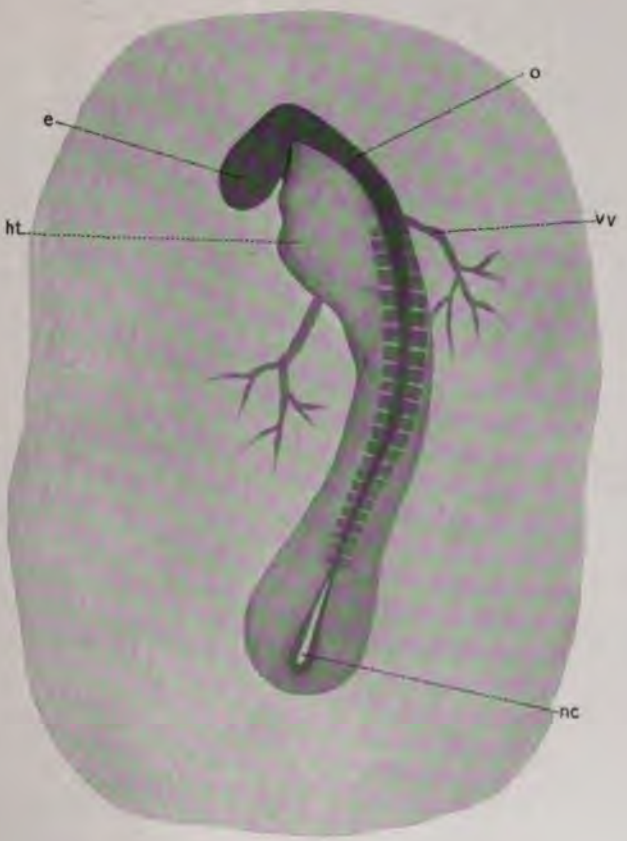


FIG. 4.

DEVELOPMENT OF DIGESTIVE CANAL OF ALLIGATOR

Property of the Library
Wisconsin Historical Society

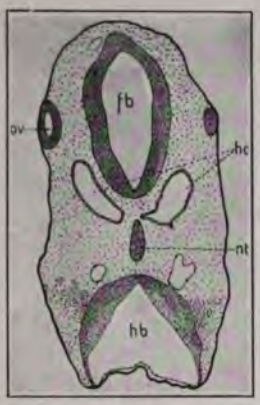


FIG. 4A.

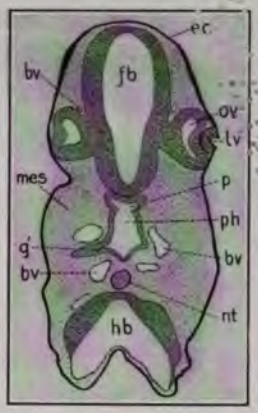


FIG. 4B.

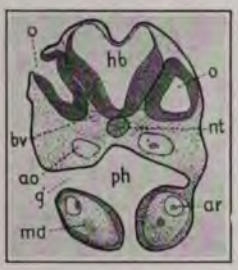


FIG. 4C.

FIG. 4D.

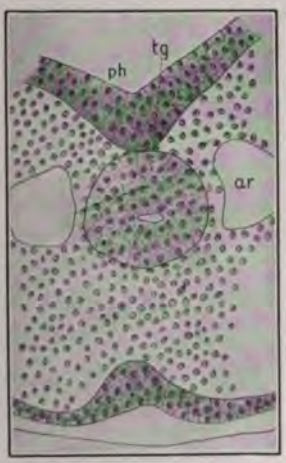


FIG. 4E.

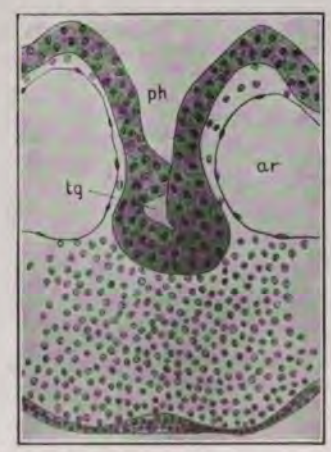


FIG. 4F.

DEVELOPMENT OF DIGESTIVE CANAL OF ALLIGATOR

CAMSCANNER

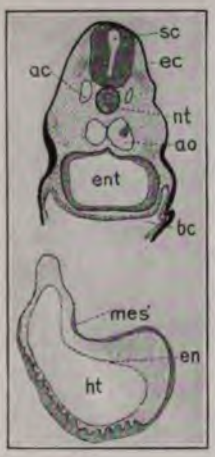


FIG. 4G.

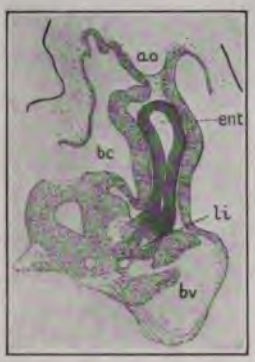


FIG. 4H.

FIG. 4K.

FIG. 4I.

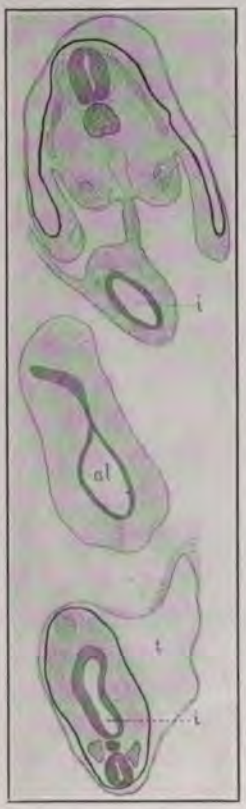


FIG. 4L.

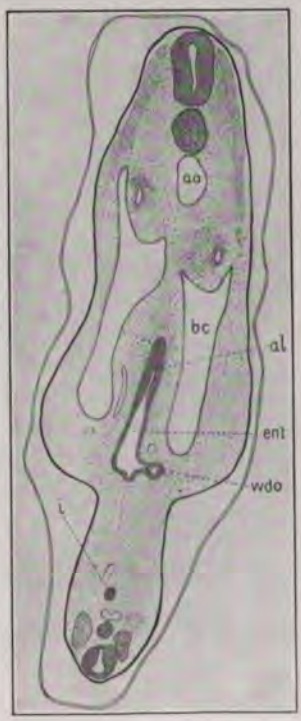


FIG. 4M.

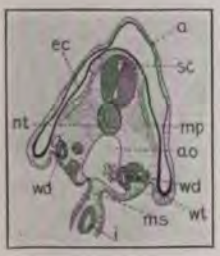


FIG. 4J.

DEVELOPMENT OF DIGESTIVE CANAL OF ALLIGATOR

Digitized by Google

FIG. 5.

FIG. 5A.

FIG. 5B.

FIG. 5C.

FIG. 5D.

DEVELOPMENT OF DIGESTIVE CANAL OF ALLIGATOR

LIBRARY OF THE MUSEUM OF COMPARATIVE ZOOLOGY

FIG. 5E.

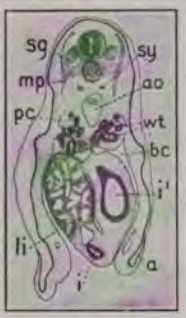


FIG. 5F.

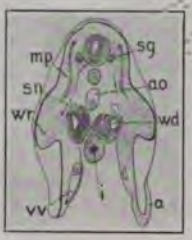


FIG. 5G.

FIG. 5H.

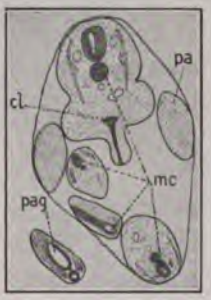


FIG. 5I.

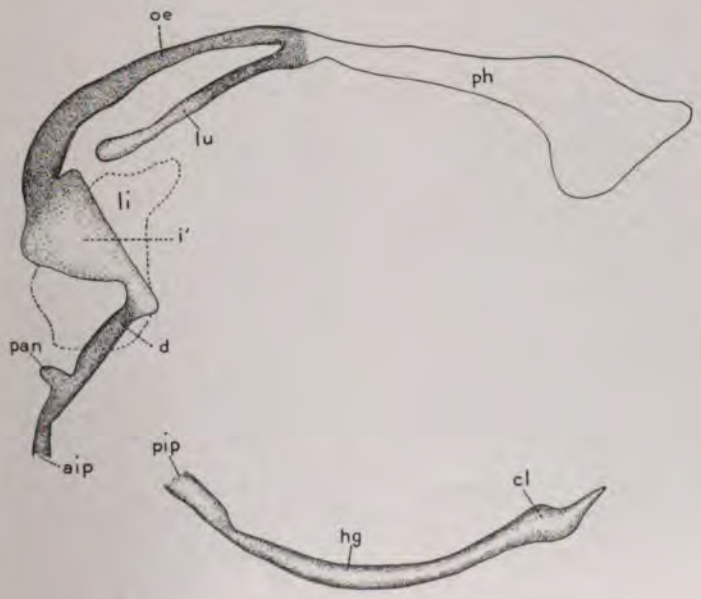


FIG. 5J.

DEVELOPMENT OF DIGESTIVE CANAL OF ALLIGATOR

FIG. 6.

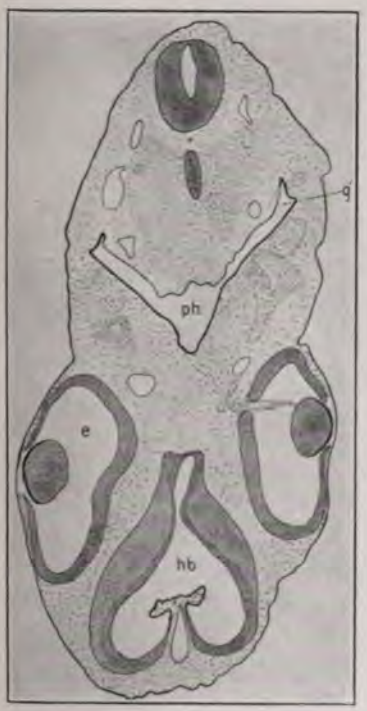


FIG. 6B.

FIG. 6C.

DEVELOPMENT OF DIGESTIVE CANAL OF ALLIGATOR

CAMSCANNER

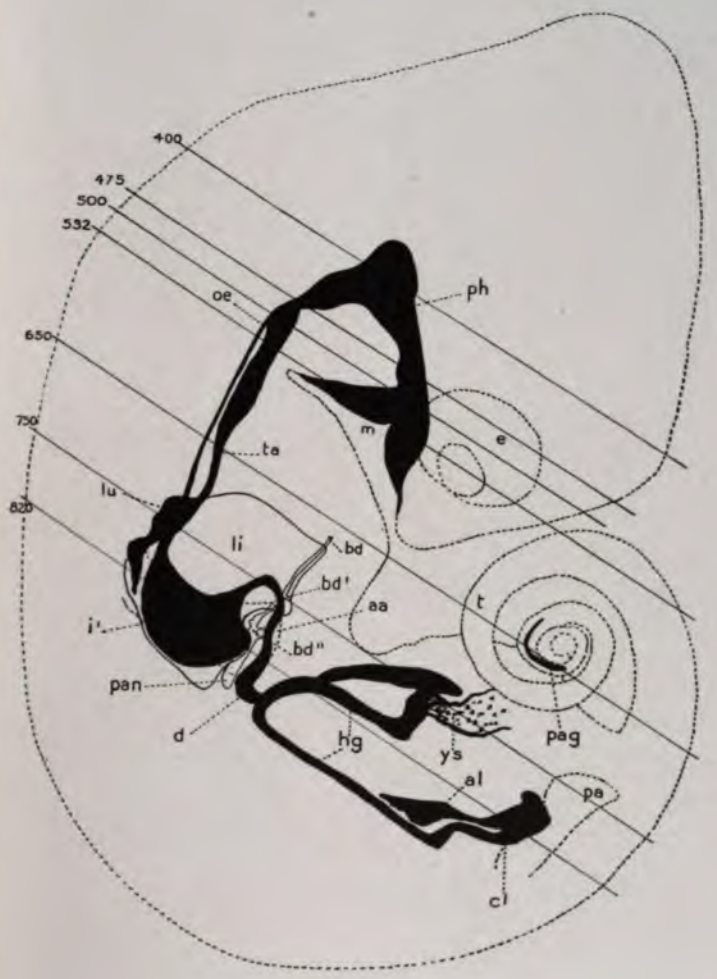

400
475
500
532
650
750
820
oe
ph
m
e
ta
lu
li
bd
bd'
aa
t
i'
bd"
pan
d
hg
ys
pag
al
pa
cl

FIG. 6A.

Digitized by the Internet Archive in 2010 with funding from Boston Library Consortium Member Libraries

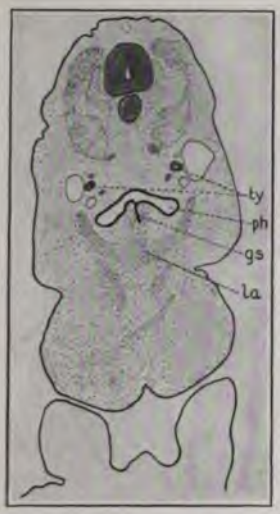


FIG. 6D.

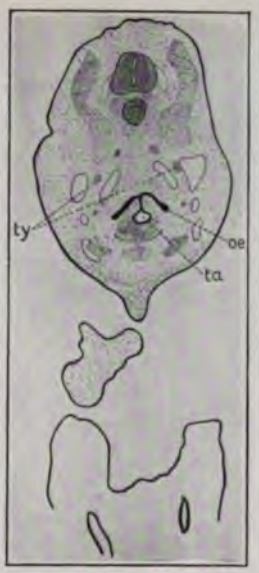


FIG. 6E.

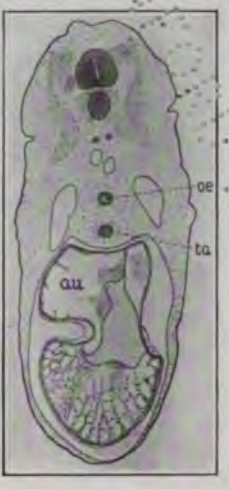


FIG. 6F.

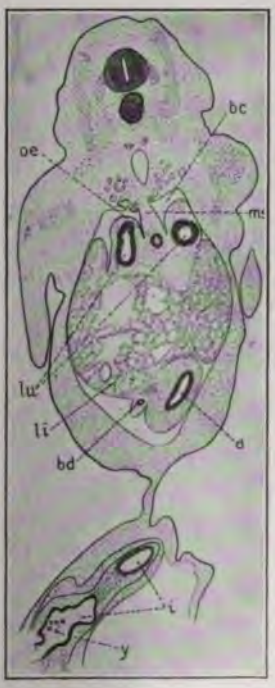


FIG. 6G.

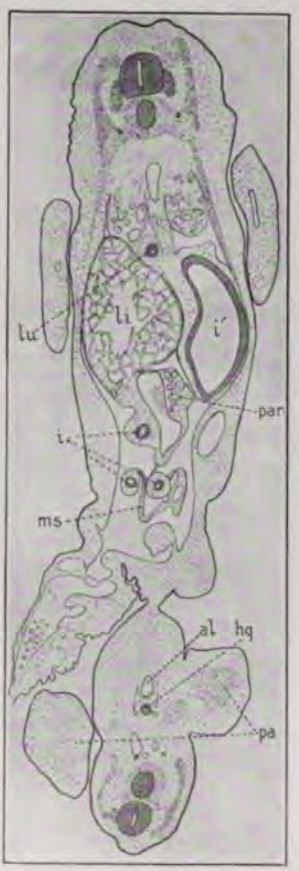


FIG. 6H.

Digitized by the Internet Archive
in 2010 with funding from
University of Toronto

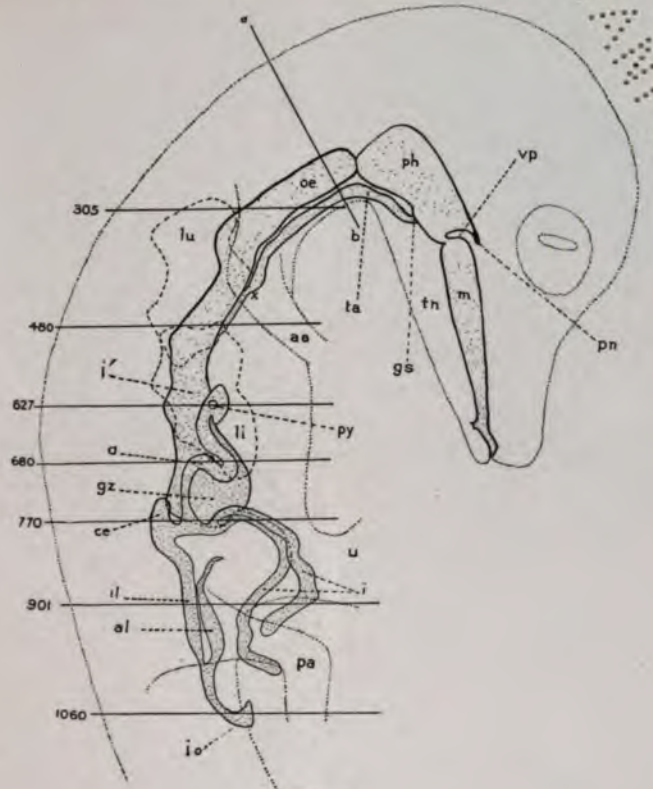


FIG. 7.

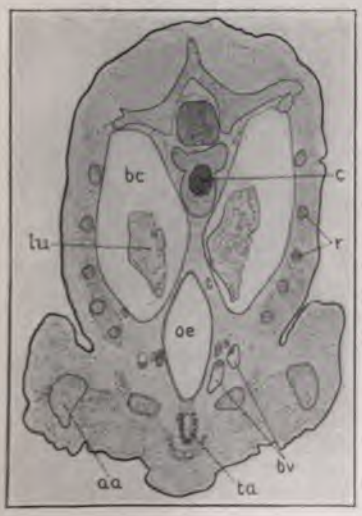


FIG. 7A.

FIG. 7B.

DEVELOPMENT OF DIGESTIVE CANAL OF ALLIGATOR

DIGITIZED BY

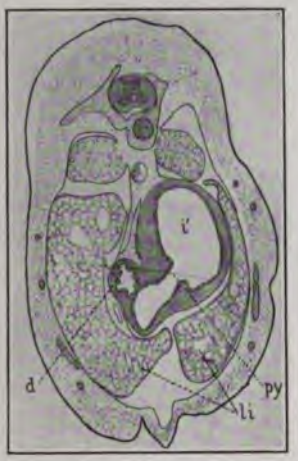


FIG. 7C.

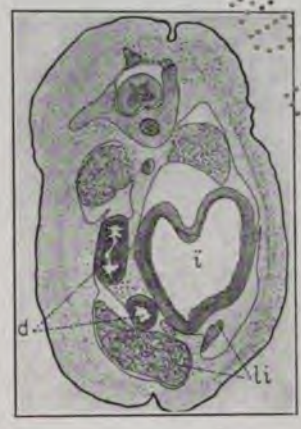


FIG. 7D.

FIG. 7E.

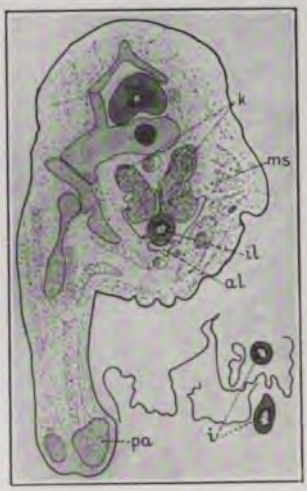


FIG. 7F.

Digitized by the Internet Archive in 2010 with funding from Boston Public Library

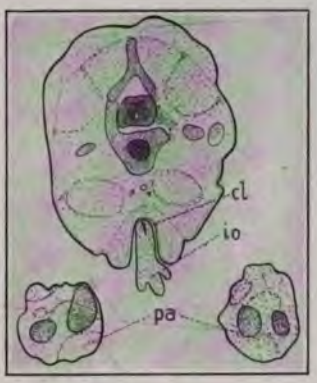


FIG. 7G.

FIG. 7H.

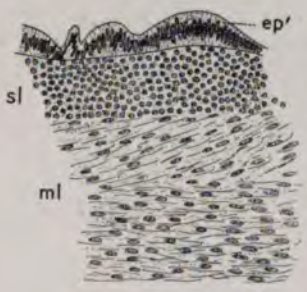


FIG. 7I.

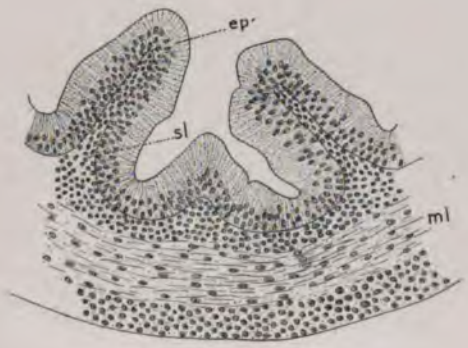


FIG. 7J.

Digitized by Google

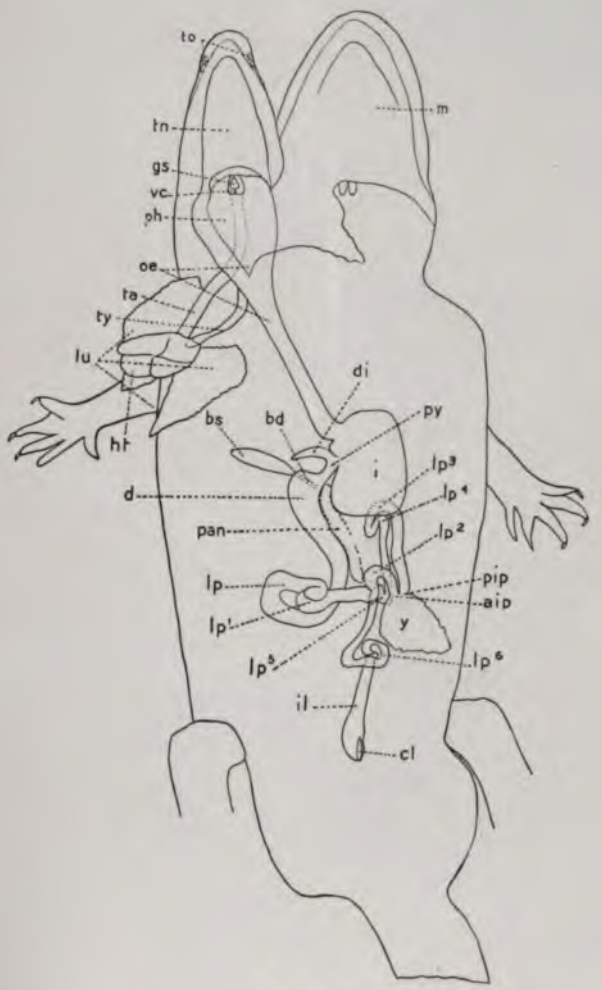

to
tn
gs
vc
ph
oe
ta
ty
lu
ht
bs
bd
di
py
i
lp3
lp4
lp2
d
pan
lp
lp1
lp5
lp6
pip
aip
y
il
cl
m

FIG. 8.

Digitized by the Internet Archive in 2010 with funding from Boston Public Library

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 56, NUMBER 12

Hodgkins Fund

THE FLYING APPARATUS OF THE BLOW-FLY

A CONTRIBUTION TO THE MORPHOLOGY AND PHYSIOLOGY OF THE ORGANS OF FLIGHT IN INSECTS

WITH TWENTY PLATES

BY
DR. WOLFGANG RITTER

(PUBLICATION 1947)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
1911

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

Hodgkins Fund

THE FLYING APPARATUS OF THE BLOW-FLY

A CONTRIBUTION TO THE MORPHOLOGY AND PHYSIOLOGY OF THE ORGANS OF FLIGHT IN INSECTS[1]

By DR. WOLFGANG RITTER

(With Twenty Plates)

CONTENTS

I. Introduction.
II. Historical survey.
III. Description:
- A. Anatomical section.
  - 1. Material and methods of investigation.
  - 2. General remarks on the thoracic skeleton of the Diptera.
  - 3. The thoracic skeleton so far as it relates to flight.
    - a. The exoskeleton.
    - b. The endoskeleton.
  - 4. The wing.
    - a. General observations.
    - b. The system of veins and folds.
    - c. The pilosity.
    - d. The flexible zone.
  - 5. The articulation of the wing.
    - a. Thoracic portion.
    - b. Intermediate parts.
    - c. Alar portion.
  - 6. The muscles of flight.
    - a. Indirect muscles.
    - b. Direct muscles.
- B. Physiological section.
  - 1. Methods of investigation.
  - 2. Flight.
  - 3. Function of muscles and joints.

IV. Synopsis of results.
V. Literature.

[1] The present investigation on the flying apparatus of the blow-fly was carried on at the Zoological Laboratory of the German University at Prague, with the assistance of a grant from the Hodgkins Fund of the Smithsonian Institution. It was under the supervision of Prof. R. von Lendenfeld of that laboratory.

I. INTRODUCTION

When I began, some two years ago, to investigate intimately the flying apparatus of the Diptera, I intended to make it a *comparative* study; but, on obtaining an insight into the literature on the flying organs of insects, I abandoned this idea because I found the necessary foundation for a comparative work wanting: there does not exist a single exact, perspicuous and well-illustrated description of a Dipterous insect. I determined, therefore, to confine my studies to a careful examination of the organs of flight in a single species.

An examination of the literature of the subject showed me how inexact the illustrations are and how difficult it is to use them to any advantage in determining the parts of the actual object. From the rough and almost useless drawings of Lowne (1890-1895) to the beautifully executed but quite schematic plates of Künckel (1875-1881), there is nothing that really approaches nature.

In order to avoid the mistakes of my predecessors I made use of photography for the graphic representations. This had not hitherto been done, and indeed it seemed unlikely that it would be possible to obtain good photographs of the thorax and wing-skeleton on account of the yellow color of the chitin forming the hard parts, and the apparent impossibility of obtaining sharp definition upon the plate of all parts of such plastic bodies as are found in the skeleton of the flying apparatus.

After many unsuccessful attempts I finally succeeded, by means of plates ("color") sensitive to yellow color and a Zeiss binocular, in producing stereoscopic views true to nature in every particular except that of color (see the section on material and methods of research). Some schematic drawings, especially of muscles, were necessary for further elucidation.

The movement of the wings was studied by means of kymographic curves and serial photographic representations of *Calliphora vomitoria* in the act of flight, made by Prof. von Lendenfeld.

I abandoned my original intention to introduce a nomenclature applicable alike to all higher insects, because I recognized that that could properly be done only by means of very extensive studies in comparative anatomy and embryology. I had, therefore, to content myself with selecting from the names already in use those which appeared to me most suitable; such old appellations as were directly contrary to the truth being replaced by new terms. At the same time I allowed myself, especially in the designation of parts not hitherto named, to be guided, as was F. Voss (1905), by the prin-

ciple that topographic relationship should be considered as of the first importance. In cases where this was not quite practicable, as, for example, in the case of the middle pieces of the wing-joint, I gave to the entire group a collective designation of a topographic character, and distinguished the separate parts by means of letters or figures. For new terms I mostly used Greek stems with Latin terminations.

And now I wish to thank most heartily my honored instructor, Professor von Lendenfeld, for his valuable advice and suggestions. Also I would thank his assistant, Dr. Emanuel Trojan, for his ever ready assistance and his interest in my work.

II. HISTORICAL SURVEY

I found in the literature but very few papers on the flying apparatus of the Diptera. The principal contributions to this subject are the work of Künckel d'Herculais on the Syrphidæ (1875-1881), in which, however, the flying apparatus is treated quite incidentally, Hammond's work on the thorax of *Calliphora vomitoria* (1879), and the monograph on the blow-fly by Lowne (1890-1895), in both of which the flying apparatus is also described very superficially.

The historical development of our knowledge of the means of flight of insects in general is summarized below.

The first notable works on this subject were published in the first half of the nineteenth century. At that time it was chiefly the French who concerned themselves with this subject, especially Latreille (1819), Chabrier (1822), Audouin (1824), and Strauss-Dürkheim (1828). At about the same time there appeared the works of Kirby and Spence (1823-1833) and Burmeister (1832). All these works treat of the entire insect world or at least of a large portion of it. Only in the second half of the nineteenth century and later have special works on the organs of flight of insects been published. The most important of these are von Lendenfeld's work on the flight of the dragon-flies (1881), Luks' articles on the musculature of insects (1883), Amans' anatomical and mechanical studies on the organs of flight in insects (1883), Adolph's description of the venation of the wings of Diptera (1885), Redtenbacher's comparative studies (1886), Marey's (1869-1872), Pettigrew's (1872-1873), and von Lendenfeld's mechanico-physiological works, and the exact description of the thorax of *Gryllus domesticus* by Voss (1905).

III. DESCRIPTION

A. ANATOMICAL SECTION

1. Material and Methods of Research

As an object of investigation the blow-fly, *Calliphora vomitoria*, was chiefly used, the Syrphidæ being also studied incidentally. The blow-fly was selected because it is easily procured in large numbers and is of considerable size. Besides, this species appeared as a favorable object because of the very strong development of its skeleton.

The first investigations were made with an ordinary microscope, but the inadequacy of this apparatus soon became apparent, and later only the binocular was used. The skeleton was studied in preparations in which the soft parts had been removed with liquor potassæ. The best results are obtained when the thoracic segments required are left at ordinary temperature about a week in a 50 per cent solution of the alkali. Boiling in the same liquid removes the muscles at once, but this method has the great disadvantage of causing the chitinous parts, chiefly the membranes and ligaments, to shrink. If the preparation appears to be too dark it can be bleached by long immersion in 50 per cent liquor potassæ. Rapid bleaching may be attained by means of a mixture of chlorate of potash and a little hydrochloric acid.

Ordinary Canada balsam preparations of the smaller and thinner parts can be made without any difficulty. The preparations of larger parts, such as median sections of the thorax, were made in the following manner. Small glass dishes with base ground flat were filled with Canada balsam dissolved in chloroform, and this was boiled until bubbles ceased to rise. The specimen was cleared up with oil of cloves and then immersed in the balsam while the latter was still warm and soft. It was then properly oriented and protected with a cover-glass.

Wings, before being placed in the balsam, were boiled in chloroform according to Walter's method (1907), and thus the tracheæ (veins) were freed from air.

Series of celloidin-sections were prepared both of parts previously treated with liquor potassæ and of parts simply hardened in alcohol. From the latter, however, no good sections of the skeleton and the smaller steering muscles could be obtained, because the very brittle chitin, especially in the complicated articular structures, broke before the knife. When the chitin was bleached and softened by

liquor potassæ it could, of course, be cut easily enough, but then it showed deformations. The results of serial sections were satisfactory only in studying the larger muscles (pl. 4A, fig. 10).

Cross-sections of the wings imbedded in celloidin were easily prepared and gave excellent results (pl. 4B, figs. 12, 13, 14).

The stereoscopic pictures which illustrate this paper were photographed with a Zeiss binocular on color plates (Weslendorp and Wehner). The contour drawings, with their lettering were produced as follows: The original stereoscopic photographs were enlarged by means of an episcope, projected upon transfer paper and copied thereon. These copies were then mounted on cardboard, provided with the lettering, and then again photographed and reduced to the size of the original stereoscopic photographs.

2. General Remarks Upon the Thoracic Skeleton of the Diptera

Apart from the much debated microthorax, the thorax of insects consists of three segments: the pro-, meso-, and metathorax. These three segments are developed very unequally. In insects capable of vigorous flight the segment or segments bearing the wings are better developed than the others. In the Diptera the mesothorax, which bears the single pair of wings, is developed much better than the other two. The prothorax is greatly reduced. In each segment there is to be distinguished: the notum or dorsal portion, usually composed of the three parts, præscutum, scutum, and scutellum; the pleuræ or lateral portions, usually composed of the two parts, episternum and epimerum; and the sternum or ventral portion.

Kolbe (1893) named the endoskeletal processes which extend inward from the notum, the pleura and the sternum: phragmæ, apodemæ and apophyses, respectively. By prefixing the syllables pro-, meso-, or meta- he designated the segment to which each belongs.

In *Calliphora vomitoria* the mesothorax forms by far the greatest part of the whole thorax. The entire back of the thorax is covered by the uncommonly well-developed mesonotum.

I should like here to make some remarks concerning the determination of the limits between the thoracic segments. Künckel d'Herculais (1875) expressed the view that the mesonotum consists of præscutum, scutum, scutellum and postscutellum. The deep notches between the parts he considers as præscutum and scutum, and the parts he considers as scutum and scutellum render it not

improbable. However, that these three pieces are primary segments of the insect's thorax and not, as Künckel and Lowne think, parts of the mesothorax. I will not here pursue this question further, and provisionally accept the ideas of Künckel and Lowne in spite of my doubts as to their correctness.

3. The Skeleton of the Thorax, so far as it Relates to Flight

The part of the thorax most important for flight is the mesothorax. In its skeleton we may distinguish exoskeletal and endoskeletal parts.

EXOSKELETAL PARTS

These are the mesonotum, the mesopleura and the mesosternum.

The Mesonotum

The mesonotum consists of four parts, the præscutum, scutum, scutellum and postscutellum.

The præscutum (pl. 1, fig. 1; pl. 2, figs. 3, 4; pl. 8, fig. 23; *p*), together with the scutum, scutellum, parapleurum and mesosternum, forms a group of the largest and strongest chitinous plates of the thorax. Beginning in the region of the cervical opening, the præscutum rises vertically upward, assumes near the limit between the first and second third of its length a horizontal position, and at the same time broadens out. From the angle between these two surfaces backward it is covered with hair. The hairs are directed backward and increase in length toward the scutellum. They are of two kinds: small, fine hairs and coarse bristles. The latter are arranged in irregular, longitudinal, and transverse rows. On the præscutum six longitudinal and three transverse rows of bristles can usually be distinguished. They fall out when the thorax is treated with liquor potassæ, and their places of attachment then appear as circular holes. The hairy covering of the back appears to be especially liable to injury. The small hairs also are often missing in many places, their points of attachment appearing as small dots. Two shallow, longitudinal furrows divide the præscutum into three zones. These are continued on the scutum but are absent on the scutellum. Ventrally, the præscutum is separated from the parapleurum by the pleural cleft. Laterally, toward the scutum, triangular areas, feebly chitinized and clear in appearance (pl. 2, fig. 3), border on the præscutum.

The scutum (pl. 1, fig. 1; pl. 2, figs. 3, 4; pl. 8, fig. 23; *s*) is the largest plate of the thorax. It is about twice as broad as long, slightly convex dorsally, and extends downward laterally in an obtuse angle to the root of the wing. Like the præscutum, it is provided with bristles which form six longitudinal and three transverse rows. Besides these rows there are usually present on its lateral parts, where the scutum bends downward, four bristles, one of which is situated on the tip of the spina scutalis (pl. 1, fig. 1; pl. 2, figs. 3, 4; pl. 8, fig. 23, *sp*). It is to be noted that the lateral parts of the scutum that slope downward toward the roots of the wings are not so strongly chitinized as the central part. Distally, these parts of the scutum are split into several parts, directly connected with the roots of the wings (see below). The scutum possesses two lateral, sharp, marginal projections, the spinæ scutales (pl. 1, fig. 1; pl. 2, figs. 3, 4; pl. 8, fig. 23, *sp*), which extend obliquely forward and downward into the cristæ spinales, which separate the two (right and left) fossæ præalares (pl. 8, fig. 23, f_1) from the fossæ postalares (pl. 8, fig. 23, *f*). These two pairs of depressions have a special relation to flight. When the wing beats upward and backward, the rigid portions, the marginal veins and the remigium, come to lie in the fossæ præalares, the flexible, posterior portions in the fossæ postalares. When the wing makes its greatest excursion backward and upward the crista spinalis adapts itself exactly to the notch between the rigid and flexible portions of the wing. This view is opposed to that held by Lowne. That observer correctly describes (1890-1892) the spina scutalis as separating the fossæ præalaris from the fossa postalaris, but in an illustration (*loc. cit.*, pl. 7, fig. 1) he shows the fossa postalaris *in front* of the spine, nearly in the position of the fossa præalaris. He correctly depicts an anterior fossa (pl. 2, fig. 3; pl. 8, fig. 23, f_{11}) at the boundary between the præscutum and the scutum, but he omits the special fossa præalaris. If the unnamed projection which appears in his drawing farther in front, near the scutum, is intended to represent the spina scutalis, it is incorrect, as this projection is in reality much nearer the scutellum.

The two processes which extend from the scutum to the root of the wing, and which articulate with the latter, are the processus præalaris (processus pteralis thoracis I; pl. 2, figs. 3, 4, *ptI*), corresponding to the fossa præalaris, and the processus postalaris (processus pteralis thoracis II; the great alar apophysis of Lowne; pl. 2, figs. 3, 4, *ptII*), corresponding to the fossa postalaris. The first

consists of two lobular parts, of which only the ventral one (the anterior præscutum of Lowne) extends right down to the root of the wing. The boundary between the two processes is formed by the cleft that runs along the crista spinalis. The ventral portion of the processus præalaris passes below into a narrow ligamentous band that thins out distally, and is attached to the inner side of the processus pteralis alæ 2 (the coracoid of Lowne, pl. 8, fig. 23, *pt2*). The processus præalaris and postalaris are connected with each other by a narrow, chitinous bridge which is very tender and easily destroyed in preparing the specimens (pl. 8, fig. 23; in all the other illustrations it is lost). The processus postalaris is a chitinous strip which decreases in size opposite the root of the wing, and has at its end a somewhat deep depression, the sella processus postalaris. In this lies, at an angle of 90 degrees, the proximal notch of the pterale A (pl. 8, fig. 24; pl. 9, fig. 25, *ptA*). Lowne calls the processus præalaris the parascutum. I have found no evidence that it should be considered as a separate piece. At the point of separation of the ventral and dorsal portions of the processus præalaris a small finger-shaped process, the processus dactyloformis (pl. 2, figs. 3, 4, *pd*), is situated. This extends dorsally into the interior of the thorax.

The scutellum (pl. 1, fig. 1; pl. 2, figs. 3, 4, *se*) has, when looked at from above, the shape of an equilateral triangle. The sides of this triangle are convex, and one of its corners is anal. The anal portion overhangs. The scutellum is beset with bristles along its edge and also bears two bristles on its back. The scutum is connected with the scutellum by the two scutellar bridges (Lowne). Along the processus postalaris extends a cleft which widens toward the root of the wing to form the foramen postalare (the supratympanic fissure of Lowne; pl. 2, fig. 3, o_1).

The postscutellum (pl. 2, fig. 3, *ps*) is cushion-shaped; upon it the scutellum rests. Toward either side it narrows considerably. I doubt whether the postscutellum belongs to the mesothorax, but, since there is not sufficient evidence in favor of any other view, I, for the present, accept this conception.

The Mesopleura

Each mesopleurum is made up of the parapleurum, episternum, parepisternum, epimerum and parepimerum.

The parapleurum (lateral plate of Lowne; pl. 2, figs. 3, 4, *pp*) is nearly quadrilateral. It is separated from the præscutum by the

pleural cleft; extends to the stigma anterius and ventrally reaches the mesosternum, with which, and with the paratrema of Lowne, it is connected by a bridge. Towards the anus a cleft, the fissura episternalis, separates the parapleurum from the episternum. A row of bristles runs along this fissure. The entire parapleurum is clothed with hair.

The episternum (pl. 2, figs. 3, 4, *e*) is narrow and dorsally reduced to the processus pterales episterni (see *C5*). Ventrally it reaches the mesosternum, analwards the epimerum.

The epimerum (pl. 2, figs. 3, 4, *ep*) has an elongated, oval shape, and is closely set with long hairs.

The parepimerum (pl. 2, figs. 3, 4, *pm*) which Lowne calls the costa, lies dorsally between the episternum and the epimerum, leans upon the latter, and like the epimerum is covered with hair.

The parepisternum (pl. 2, figs. 3, 4, *pe*) lies dorsally upon the epimerum. I give it this name because it is closely connected with the episternum. It is triangular and considerably thickened on one side in the form of a pediculated bud. Here, as in the case of the stroma of the processus pteralis thoracis, we may make an exception to the rule that names implying form should not be used, and from its uncommonly impressive and striking bud-like shape, call it the *calyx*.

The Mesosternum

The mesosternum (pl. 1, fig. 2; pl. 2, figs. 3, 4, *es*) consists of two symmetrical halves, from each of which a process extends to the anterior pair of stigmata. These halves are nearly quadrilateral in shape and strongly curved. With the two metasternums they form the principal part of the central portion of the thorax. They unite in the median plane, bend inwards (upwards), and form, when united, the mesosternal process (furca of the mesosternum, Lowne; pl. 1, fig. 2, *ap;* see also below under Endoskeleton). The "lateral plate of the postscutellum" of Lowne should be mentioned in passing as it is connected with the wing through the squama. It is approximately triangular, strongly convex, and separated from the processus postalaris by the foramen postalare (supratympanic fissure of Lowne).

ENDOSKELETAL PARTS

The endoskeletal parts that are here to be considered are the præscutal crest, the mesapodema, which is continued into the episternal border, the mesapophysis and the so-called parapterum.

The præscutal crest. A narrow endoskeletal crest arises from the dorsal side and projects inward. This cannot be considered as a phragma. I name this the præscutal crest (pl. 2, fig. 4, *l*). It arises from the boundary between the præscutum and the paratrema, bridges the former, follows the ventral edge of the præscutum, and ends at the boundary between the præscutum and the scutum. Here it is connected by ligamentous attachments with the parapterum (pl. 2, fig. 4, *pn*).

The mesapodema (great entopleuron, Lowne; pl. 1, fig. 2; pl. 2, fig. 4, *a*) arises at the ano-dorsal curvature of the mesosternum. It does not wholly correspond to the apodema of Kolbe, but as it belongs almost entirely to the pleural portion of the thorax I will retain the above designation. Farther on the mesapodema follows the curvature of the mesosternum as far as the parapleurum to the anal and ventral corner of which it is attached. From here it extends, in the shape of a crest, above the boundary between epimerum and episternum (pl. 2, fig. 4; pl. 10, fig. 28, l_1) to the root of the wing. I call this crest the *episternal crest* because it is attached to a process of the episternum, the processus pteralis thoracis IV. The episternal crest gradually passes into a tendinous ligament. The mesapodema bends first towards the anus and so forms, with the episternum, the episternal pouch, then it turns toward the head and projects toward the interior as a strong, jagged protuberance, the processus serratus (pl. 1, fig. 2, *a*).

The mesapophysis (pl. 1, fig. 2, *ap*) consists properly of two pieces, belonging to the two mesosternums. As already mentioned, the two mesosternums are joined to a single plate which projects vertically upwards into the interior (pl. 1, fig. 2, *ap*). This plate narrows distally, and finally again divides into two stalk-like pieces. These stalks diverge from each other and bear at their ends twisted cup-like enlargements, the processus alveolati (pl. 1, fig. 2, *ap*).

In conclusion, there should be mentioned a peculiar skeletal structure, the so-called

Parapterum (Audouin, Lowne; pl. 2, fig. 4, *pn*). This lies near the parapleurum, and is not firmly attached to any portion of the skeleton. It consists of a stalk-like part, the stem, which terminates in an enlargement, the head. The anal portion of the head reaches as far as the root of the wing, while the rostral portion, as already mentioned, is united by a ligament to the end of the præscutal border. The parapleurum serves, as do the above-mentioned endoskeletal

structures proper, as surfaces of attachment for the muscles. (See Chapter VI.)

Near the root of the wing there are found two large openings in the lateral wall of the thorax, through which direct muscles of flight pass to the wing joints: the foramen præalare (pl. 2, fig. 3, *o*) and the foramen postalare (pl. 2, fig. 3, o_1).

4. The Wing

A. GENERAL OBSERVATIONS

The wing of *Calliphora vomitoria* (pl. 3, figs. 5, 6; pl. 5, figs. 15-17) is, when fully expanded, irregularly oval. It is, according to the size of the fly, usually 8.5 to 11 mm. long and 3.4 to 4.6 mm. in maximum width. Its horizontal projection (outline) has an extent of from 20 to 40 square millimeters. Its anterior margin appears as a continuous convex line. The curvature is slight at the base and in the middle, but increases distally and is most marked at the tip of the wing. The posterior margin is, on the whole, convex like the anterior, but notched in three places. The most distally situated notch is insignificant and situated a short distance distally from the middle of the wing. The two other notches are deep incisions and situated, proximally, near the root of the wing. They separate two small lobes from the main portion of the wing. The proximal lobe (nearest the body) is the squamula (text figure 2; pl. 5, figs. 15, 17, *Sq*), the distal lobe which lies between the two deep incisions is the lobulus (text figure 2; pl. 5, figs. 15, 17, *lo*).

B. THE VEINS AND FOLDS

The wing is, as Marey recognized in 1869, somewhat warped and slightly convex above. Large and small folds, the former up to 100 μ in height, traverse the wing longitudinally. In the proximal part of the wing 8, and in its distal part 10 folds are to be distinguished. These folds decrease in height distally as they approach the margin of the wing. The anterior large folds are nearly parallel to the anterior margin of the wing, and extend to its end; the posterior smaller folds radiate somewhat in a fan-shaped manner and extend obliquely outward and backward. These folds disappear before reaching the margin of the wing. The posterior portion of the wing is creased by very small folds. These folds are numerous, closely crowded and directed backward and outward (pl. 5, figs. 15-17).

I shall now describe the eight longitudinal veins.

Gi, the marginal vein (text fig. 2; pl. 5, figs. 15, 17; pl. 8, figs. 23, 24, *gi*), begins with a club-shaped swelling at the processus pteralis alæ 1. It is notched in the flexible zone (vide infra), and extends, gradually diminishing in thickness, as far as the medio-marginal transverse vein of Lowne (text fig. 2; pl. 5, figs. 15, 17, q_1).

The four following veins are joined basally to a single vein, the remigium (text fig. 2; pl. 5, figs. 15, 17; pl. 8, figs. 23, 24, *re*), which appears as a short and very strong tube. The remigium is the strongest vein of the entire wing.

Iaa, the auxiliary vein (*mediastinal*) (text fig. 2; pl. 5, figs. 15, 17; pl. 8, figs. 23, 24, *Iaa*) arises at the point where the anterior transverse vein (*at*) touches the remigium. Basally, in the flexible zone, it exhibits a transverse striation (vide infra).

Iba (*subcostal*) (text fig. 2; pl. 5; figs. 15, 17; pl. 8, figs. 23, 24, *Iba*) arises from the remigium and is about its middle strengthened by a swelling.

IIaa (*radial*) (text fig. 2; pl. 5, figs. 15, 17; pl. 8, fig. 23, *IIIaa*) and

IIIba (*ulnar*) (text fig. 2; pl. 5, figs. 15, 17; pl. 8, fig. 23, *IIIba*) arise together from the remigium. They are connected with the latter by a piece which exhibits particularly clearly the transverse striation of the veins in the flexible zone (pl. 7, figs. 20, 21, 22). The place of common origin of these two veins is thickened and set with bristles. Between these two veins there are two high folds, one projecting upward (convex), *IIba*, the other projecting downward (concave), *IIIaa*.

Iam. Discoidal vein (*median*) (text fig. 2; pl. 5, figs. 15, 17; pl. 8, figs. 23, 24, *Iam*). This is the first vein of the median area; it forms, with the *IIbm* and the transverse vein of the knee, the knee of the wing (*fk*). It is connected with *IIba*, proximally, by the transverse vein of the knee (patagio-hypocostal), farther on by the median transverse vein (*q*), and at the tip by the medio-marginal transverse vein q_1 with the end of the marginal vein. Between *Iam* and *IIIba* are found the folds *IVaa* and the *Spuria*, *IVba*.

IIbm (*submedian*) (same figs.) extends in the crest of a strongly protruding, convex fold right to the posterior margin of the wing. It arises from the knee of the wing and is connected with *Iam* by two transverse veins; the postical transverse (*po*) and the discoidal-

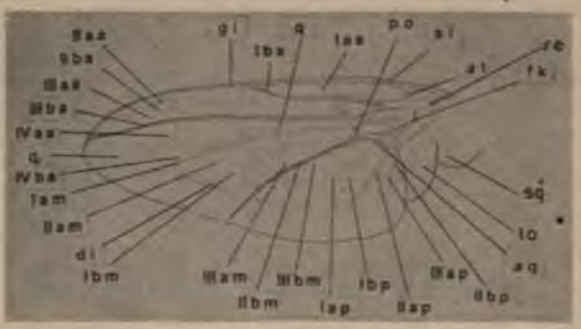


FIG. 2. Scheme of the wing.

Longitudinal folds (longitudinal veins):

gi, Anterior margin, marginal vein.
Iaa, First depressed (concave) fold of the anterior region, auxiliary vein.
Iba, First raised (convex) fold of the anterior region, subcostal vein.
IIaa, Second depressed (concave) fold of the anterior region, radial vein.
IIba, Second raised (convex) fold of the anterior region.
IIIaa, Third depressed (concave) fold of the anterior region.
IIIba, Third raised (convex) fold of the anterior region, ulnar vein.
IVaa, Fourth depressed (concave) fold of the anterior region.
IVba, Fourth raised (convex) fold of the anterior region, spuria.
Iam, First depressed (concave) fold of the middle region, discoidal vein.
Ibm, First raised (convex) fold of the middle region.
IIam, Second depressed (concave) fold of the middle region, division vein.
IIbm, Second raised (convex) fold of the middle region, submedian vein.
IIIam, Third depressed (concave) fold of the middle region.
IIIbm, Third raised (convex) fold of the middle region.
Iap, First depressed (concave) fold of the posterior region, anonyma.
Ibp, First raised (convex) fold of the posterior region.
IIap, Second depressed (concave) fold of the posterior region, anal vein.
IIbp, Second raised (convex) fold of the posterior region, axillary vein.
IIIap, Third depressed (concave) fold of the posterior region.

Other parts:

aq, Transverse anal vein.
at, Anterior transverse vein.
di, Discoidal transverse vein.
fk, Knee of the wing.
lo, Lobulus.
po, Posterior transverse vein.
q, Median transverse vein.
q_1, Medio-marginal transverse vein.
re, Remigium.
si, Notch of the marginal vein in the flexible zone.
sq, Squamula.

transverse (*di*). Between *Ibm* and *Iam* are found the folds *IIam* (division vein), *Ibm* and *IIIam.*

IIap, the anal vein (same figs.), does not arise from the knee of the wing, as is shown by Lowne in his illustration (1890-1895, v. I, pl. 10, fig. 1), but reaches as far as the *tau* of Lowne, that is, the inner marginal vein of the lobulus (*l. c.*, pl. 9, fig. 25; pl. 11, fig. 29, *ie*). It articulates with a branch of this vein by a protuberance at its base. This arrangement acts as a stop that prevents the anal portion of the wing from flapping too far downward. The anal vein is connected with the knee only by means of a band of chitin which, however, is not visble from above because it is covered by the knee of the wing. The anal vein is connected with the *IIbm* by the transverse anal vein (*aq*). Between the two last-named longitudinal veins lie the folds: *IIIbm, Iap,* the anonyma, the boundary between the area media and the area postica, and *Ibp.*

IIbp, the axillary vein (same figs.), is very feeble; it can just be made out as a vein. It arises at the tip of the inner marginal vein of the lobulus, with which it forms an acute angle. The last fold is *IIIap.*

The longitudinal and transverse veins divide the wing into the following fields (Lowne, 1890-1895):

The regio mediastinalis between *gi* and *Iaa.*[1]
The regio subcostalis between *Iaa* and *Iba.*
The regio marginalis between *Iba* and *IIaa.*
The regio cubitalis between *IIaa* and *IIIba.*
The regio præpatagialis between *IIIba* and *Iam,* proximal.
The regio subapicalis between *IIIba* and *Iam,* distal.
The regio apicalis between q_1 and terminal border, distal.
The regio anterior basalis between *Iam* and *IIbm,* proximal.
The regio discoidalis between *Iam* and *IIbm,* distal.
The regio posterior basalis between *IIbm* and *IIap,* proximal.
The regio patagialis between *IIbm* and *IIap,* distal.

At the posterior border of the wing, in the regiones subapicalis, apicalis, discoidalis and patagialis there are found numerous small transverse folds, which extend toward the posterior border.

All the veins taken together appear as a net or framework composed of tubes, the meshes of which are occupied by the double hairy lamella that forms the wing plate. The lamella of the wing has a certain firmness. This prevents the posterior part, which is not supported by any veins, from collapsing.

[1] I use the term regio instead of area (Lowne) in order to avoid a confusion with the terms area antica, media, etc.

THE PILOSITY

The anterior marginal vein bears large and small hairs which are directed obliquely forward, upward and outward. On its first [illegible] the large hairs form two rows; proximally, the large hairs [illegible] and inside the notch (pl. 6, figs. 18. [illegible] large bristles. The small hairs are [illegible] large. The [illegible] lamella) is also [illegible] pl. 4B, figs. [illegible] These are curved. The [illegible] curvature [illegible] the direction [illegible] vein or [illegible] The hairs [illegible] and the [illegible] the same [illegible] by the [illegible] anal portion [illegible] hairs [illegible] marg[illegible] hair [illegible] ventral [illegible] photograph[illegible] the [illegible]

migium divides into three separate veins. The parts of these veins, especially of *IIaa* and *IIIba*, which are here still united, passing through the flexible zone, are lighter colored than their other parts. This lighter coloring is caused by the strong, dark chitin being here restricted to narrow, transverse belts, separated by belts of similar width, composed of weak and pale chitin (pl. 7, figs. 20, 21, 22). This portion of the vein is similar in structure to the ordinary tracheæ within the body, except that the strong and dark chitin does not here form a continuous spiral band, but transverse belts or bars.

5. The Articulation of the Wing

(Pl. 8, figs. 23, 24; pl. 9, figs. 25, 26.)

The skeletal parts forming the articulation of the wing can be divided into three groups:

a. The thoracic parts (processus pterales thoracis).
b. The intermediate parts (pteralia), and
c. The alar parts (processus pterales alæ).

In naming these parts I have avoided all terms relating to form or function and have designated them by letters and figures. I selected for the processus pterales Roman figures, for the pteralia capital letters, and for the processus pterales alæ Arabic figures (for example Proc. pter. al. 1, etc.). This method is more practical than the application of the terms used for analogous, but in no way homologous, parts of the vertebrate skeleton to the insect skeleton. In certain cases where I have either been able to ascertain the function of a part, or where its form is so striking that it easily impresses itself upon the memory, I propose to substitute, for better orientation, instead of the above-mentioned designations, short terms such as calyx, stroma, etc. For the processus pterales thoracis I and II the well-founded, older names processus præalaris and postalaris will be retained. Besides the parts belonging to the above-mentioned groups there are others found in the articulation of the wing which may be designated as stays.

A. The thoracic portion (processus pterales thoracis)

This portion consists of six pieces:

1. *Processus pteralis thoracis I* (Processus præalaris) (pl. 2, figs. 3, 4; pl. 8, fig. 24; pl. 9, fig. 25, *ptI*).

Described above with the scutum.

2. *Processus pteralis thoracis II* (Processus postalaris) (pl. 2, figs. 3, 4; pl. 8, figs. 23, 24; pl. 9, fig. 25, *ptII*).

Described above with the scutum.

3. *Processus pteralis thoracis III* (pl. 2, figs. 3, 4; pl. 9, fig. 26; pl. 10, figs. 27, 28, *ptIII*). This process is the pra-epaulet of Strauss-Dürkheim (1828). It arises at the episternum, narrows to a thin band that suddenly broadens distally to a semi-circular piece, and is then drawn out into a delicate band which passes into the membrane (see pl. 9, fig. 26) inserted upon the processus pteralis alæ 3 below the pterale B (pl. 9, fig. 26, *ptB*).

4. *Processus pteralis thoracis IV* (pl. 2, figs. 3, 4; pl. 9, fig. 26; pl. 10, figs. 27, 28, *ptIV*). This process is the "great ampulla" of Lowne. According to its function and form it may be designated as *stroma* (cushion). It is a protruding cushion-shaped piece, united with the episternum by means of a broad band, and situated in the axillary cavity of the thorax. Between the distal end of this piece and the head of the processus pteralis thoracis III there is a triangular stay (pl. 9, fig. 26; pl. 10, figs. 27, 28, *st*).

5. *Processus pteralis thoracis V* (pl. 4A, fig. 11; pl. 9, fig. 26; pl. 10, figs. 27, 28, *ptV*). Four pieces combine to make up this process: the episternum, the parepisternum, the stroma and the episternal border. Three strongly chitinized bands arise from the episternum. These finally unite with the episternal border to form a strong chitinous bar which bears at the end the process. The process itself appears as an inflation. It bears, proximally from the stroma, three small spines and distally one larger one. The entire process somewhat resembles a comb with a handle.

6. *Processus pteralis thoracis VI* (pl. 8, fig. 24; pl. 9, fig. 26; pl. 11, fig. 29; *ptVI*). This process arises from the crest that runs along the "lateral plate of the postscutellum" (Lowne) and is joined to the squama. It is a short, distally thickened, chitinous piece, which shows a saddle-like depression that corresponds with a similar saddle surface in the processus pteralis alæ 4 (pl. 11, fig. 29, *pt4*).

2. THE INTERMEDIATE PARTS (PTERALIA)

This group consists of three pieces:

1. *Pterale A* (pl. 3, fig. 8; pl. 4A, fig. 9; pl. 8, figs. 23, 24; pl. 9, fig. 25; *ptA*). This pterale is the "dens" of Lowne. It bears four large protuberances, two shorter proximally, and two longer distally directed ones. One of the proximal ones extends into the interior

of the thorax. This protuberance is the processus duplicatus (pl. 3, fig. 8; pl. 4, fig. 9, *du*). It is divided into two secondary protuberances by a shallow saddle. The proximal protuberances ride, as it were, on the sella processus postalaris. Of the distal protuberances, one, the processus analis (pl. 3, fig. 8; pl. 4, fig. 9, *an*), is directed anally, the other rostrally. The former corresponds to the notch in the processus pteralis alæ 4; the latter, the processus rostralis (same figs., *ro*), clasps the pterale B (pl. 8, fig. 24; pl. 9, fig. 25, *ptB*) and extends as far as the processus pteralis alæ 2.

2. *Pterale B* (pl. 3, fig. 7; pl. 8, fig. 24; pl. 9, figs. 25, 26; *ptB*). This pterale is the unguiculus of Lowne. It is situated vertically and connects the upper and under sides of the joint. From the upper side a strong protuberance, the processus proximalis (pl. 3, fig. 7, *x*) arises. This protrudes beyond the processus rostralis of pterale A. From the lower side two important protuberances, the processus dentales (pl. 3, fig. 7, *de*), arise. In the space between these two protuberances lies the anal convexity of the processus pteralis thoracis V. Besides those mentioned above there are three smaller protuberances which appear to be of minor importance.

3. *Pterale C* (pl. 9, fig. 26, *ptC;* pl. 10, figs. 27, 28, *ptC*). This pterale is the hypopterigium of Lowne. It consists of a skeletal piece surrounded by a hyaline elastic mass. The skeletal portion has somewhat the form of a pistil with a strongly expanded head and a conical stem. Pterale C is in contact with the stay *V*. The head of the pterale lies in the deep, strongly chitinized, articular fossa of the processus pteralis alæ 3 (see pl. 9, fig. 26).

C. THE ALAR PORTION (PROCESSUS PTERALES ALÆ)

The marginal vein and the remigium form the principal part of the alar portion of the joint. The remaining proximal parts of the wing take hardly any part in its formation.

Four processus pterales alæ are to be distinguished:

1. *Processus pteralis alæ 1* (pl. 8, figs. 23, 24; pl. 9, figs. 25, 26; *pt1*). This process appears as a continuation of the club-shaped basal protuberance of the marginal vein. It resembles a hand held hollow, articulates with the processus pterales alæ 2 and 3, and is separated from the marginal vein by a sharp incision and a clear, feebly chitinized zone. Rostrally, it is covered by a scale-like, hairy piece, the *tegula* (pl. 8, figs. 23, 24; pl. 9, figs. 25, 26, *t*), which extends over the whole joint. The names pre-epaulet, epaulet and subepaulet, with which Strauss-Dürkheim designated different portions

of this piece, and which Lowne afterward adopted, I do not consider suitable.

2. *Processus pteralis alæ 2* (pl. 8, figs. 23, 24; pl. 9, fig. 25; *pt2*). This process arises dorsally from the remigium. It has the shape of a rectangle with rounded corners, to which an oval piece is attached proximally. This oval piece extends distally to a notch of the remigium, into which it fits. As already stated the rectangular piece is embraced by the processus pteralis alæ 1. The processus pteralis alæ 2 is connected with the processus præalaris by a ligament.

FIG. 3. View of the proximal part of the remigium from below. Diagrammatic. (Magnification 80.)

pt. 2, Processus pteralis alæ 2.
pt. 3, Processus pteralis alæ 3.

3. *Processus pteralis alæ 3* (pl. 9, fig. 26; text fig. 3; *pt3*). This process is attached ventrally to the remigium. Its form reminds one of a compressed cornet or cone with oval base. It might be considered as having arisen from the ventral border of the remigium, which is, in this region, trough-shaped, being bent outward. The anal part of the curved surface is strongly chitinized, the part turned toward the marginal vein only slightly so, and compressed.

The head of pterale C fits into this strongly chitinized cavity, and thus the asymmetrical form of this pterale finds its explanation in the asymmetry of the processus pteralis alæ 3.

4. *Processus pteralis alæ 4* (pl. 8, fig. 24; pl. 9, figs. 25, 26; pl. 11, fig. 29; *pt4*). Before taking this processus into consideration I shall describe the inner marginal vein of the lobulus, with which it is closely connected. The deep incision which separates the lobulus (text fig. 2; pl. 5, figs. 15, 17; pl. 11, fig. 29, *lo*) from the wing proper extends as far as the origin of the axillary vein. The proximal part of this vein is a strongly chitinized thickening of the wing-lamella, and connected with the anal vein. This thickening forms at the same time the point of origin of an elevated (convex) fold which extends to the tau of Lowne (1890-1895, vol. 1, pl. 10, *t*) and passes into it. The crest of the fold, together with the tau, form the margin of the lobulus, and are together to be considered as its inner marginal vein (pl. 11, fig. 29, *ie*). The proximal end of this vein loosely articulates by means of a sort of ball and socket joint with the posterior (anal) marginal thickening of the squamula (see pl. 11, fig. 29). This marginal thickening bends downward and inward, and passes into the processus pteralis alæ 4, which is, in truth, the proximal, terminal portion of the inner marginal vein of the squamula. As the proximal end of this is strongly chitinized and differentiated as an articulating part, I reckon it among the processus pterales. The processus pterale alæ 4 has a depression into which fits the anal process of pterale A. The surface of the terminal portion of the processus pterale alæ 4 is in one place saddle-shaped. This saddle fits, as already stated (see thoracic portion), onto the saddle of the processus pterale thoracis II. Between the remigium and the processus pterale alæ 4 lies a stay (pl. 9, fig. 25, v_1) which occupies the entire space between these structures and pterale B. It is especially well developed near the processus pterale alæ 4, where it is thickened to a disk. This stay is connected with the remigium by a strip of chitin (pl. 9, fig. 25). The parts of the joint are united by a chitinous membrane, and they can be considered as strong, local thickenings of this membrane. These articulating parts may well be considered as originating, so far as they are independent of the veins, from stimulations acting on the covering membrane so as to induce them to increase in thickness locally. The uniting membrane is flexible, but of considerable tensile strength.

The foramina præalaris and postalaris are bridged over by loose ligaments: the ligamenta præalare and postalare.

6. The Muscles of Flight

The best way to study the muscles of flight is to make a median section of the thorax to work down laterally from this, and to observe with a binocular microscope. The illustrations to this paper relate throughout to preparations made and examined in this way. They show the successive muscular layers thus rendered visible.

Two kinds of muscles of flight are to be distinguished: indirect and direct. The former act indirectly upon the wings by compressing

Fig. 4. Diagrammatic view of the median indirect muscles. (Median section of the thorax.)

ap, Mesapophysis.
dvI, Musculus dorso-ventralis primus.
dvII, Musculus dorso-ventralis secundus.
lu, Air-sac.
m, Musculus latus.
mm, Musculus dorsalis.

the breast longitudinally and vertically; the latter are attached to the roots of the wings and move them directly. The number of direct muscles is larger than is generally supposed; in *Calliphora vomitoria* there are no less than ten pairs. In the Libellulidæ, where only direct muscles of flight occur (von Lendenfeld, 1881, p. 344), these muscles are correspondingly strong. In the Diptera, where the chief work of flight is performed by the indirect muscles, these

are very well developed, while the direct muscles which serve chiefly for steering are small and weak.

Künckel (1875, p. 175) divides the entire musculature of the Diptera into three groups, the depressors (abaisseurs), the elevators (elevateurs) and the steering muscles (directeurs). The depressors and elevators are indirect, the steering direct muscles.

A. INDIRECT MUSCLES

A pair of powerful muscles, the musculi dorsales (Künckel, 1875, p. 175) (text fig. 4, *mm;* pl. 4, fig. 7, *mm;* pl. 12, fig. 31, *mm*) trav-

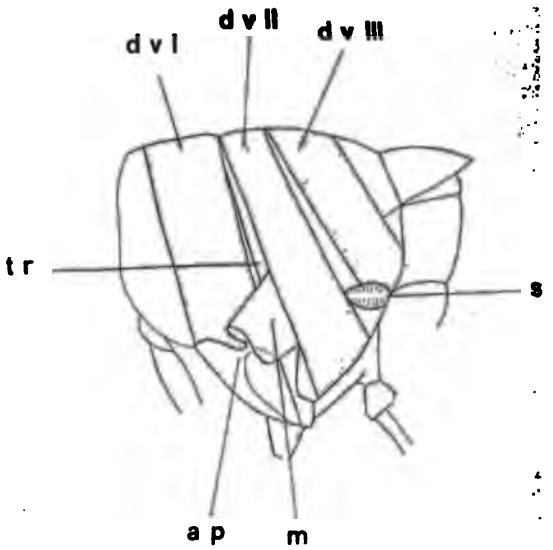


FIG. 5. Diagrammatic view of the more laterally lying indirect muscles. (Median section of the thorax.)

ap, Mesapophysis.
dvI, Musculus dorsalis-ventralis primus.
dvII, Musculus dorsalis-ventralis secundus.
dvIII, Musculus dorsalis-ventralis tertius.
m, Musculus latus.
st, Stigma anterius.
tr, Trochanter muscle.

erse the entire length of the thorax. Each of these consist of six separate parts of unequal length. The first, dorsal portion, extends from the boundary between the scutellum and postscutellum of the mesothorax to about the middle of the scutum, where it is inserted. Between this muscle, the scutellum and the anal portion of the scutum there is an empty (air-filled) space (pl. 12, fig. 31, *lu*) which is to be regarded as an air-sac.

Laterally from the two dorsal muscles, there are three powerful dorso-ventral muscles (text figs. 4, 5; pl. 4, fig. 32, *dv*), each of which appears to be composed of four parts. The first three I designate with the numbers from I to III. The fourth is apparently not a muscle of flight.

The musculus dorso-ventralis I (text fig. 5; pl. 12, fig. 32; *dvI*) is the strongest. It extends from the dorsal portion of the præscutum to the mesosternum.

The musculus dorso-ventralis II (text fig. 5; pl. 12, fig. 32; *dvII*) extends from the rostral portion of the scutum to the metasternum.

The musculus dorso-ventralis III (text fig. 5; pl. 12, fig. 32; *dvIII*) is attached to the scutum behind the musculus dorso-ventralis II, and extends to the "tympanic plate" of Lowne (s. l., 1890-1892, t. 7, figs. 2, 24), to the thickened margin of which it is fixed.

The fourth dorso-ventral muscle (text fig. 5; pl. 12, fig. 32, pl. 13, fig. 33; *tr*), which is much the weakest of the four, must, from its position, be considered as a leg muscle. It arises from the scutum, at the edge of the præscutum, lies under the turbinate process of the mesapophysis, and is inserted on the trochanter of the second pair of legs.

As an indirect muscle of flight the broad, ribbon-like musculus latus is also to be mentioned. It lies between the mesapophysis and the mesapodema.

B. DIRECT MUSCLES

As mentioned above, ten direct muscles are to be distinguished on either side.

1. *The adductor alæ* (text fig. 6; pl. 13, fig. 33; *md*). This muscle arises in the shape of a broad band from the mesapodema. Gradually attenuated, it extends to the foramen postalaris. It then becomes tendinous and passes through this foramen and is continued beyond in the ligamentum postalare, stretched out between the processus pteralis thoracis VI, the processus pteralis alæ 4, the processus postalaris and the pterale A.

2. *The abductor alæ primus* (text fig. 6; pl. 13, fig. 33; *mbI*). This muscle arises from the point where the parapleurum, the stigma anterius and the præscutum come in contact, close under the præscutellar edge. The muscle follows this edge, becomes broader distally, and attaches itself to the parapterum.

3. *The levator alæ primus* (text fig. 7, pl. 11, fig. 30, pl. 13, fig. 34; *mel*). This muscle is delta-shaped. It arises at the ventral,

somewhat thickened edge of the parapleurum and passes into a long, delicate tendon which is attached to the processus duplicatus of pterale A.

4. *The levator alæ secundus* (text fig. 6, pl. 11, fig. 30, pl. 13, fig. 34; *meII*). This muscle is rhombic in shape. It arises close to the mesapodema, at the boundary between the parapleurum and the mesosternum, and passes into a strong tendon which follows the episternal border alongside the supinator; apparently united with the tendon of that muscle, it passes to the foramen præalare.

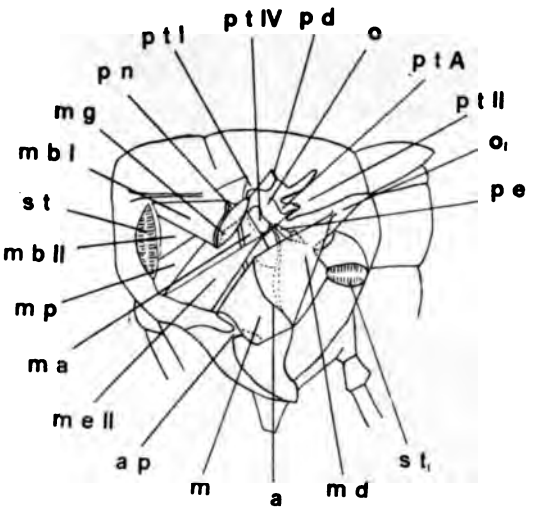


FIG. 6. Diagrammatic view of the direct muscles that lie nearer the median plane. (Median section of the thorax.)

a, Mesapodema.
ap, Mesapophysis.
m, Musculus latus.
ma, Musculus anonymus.
mbI, Musculus abductor alæ primus.
mbII, Musculus abductor alæ secundus.
meI, Musculus levator alæ primus.
meII, Musculus levator alæ secundus.
md, Musculus adductor alæ.
me, Musculus gracilis.
mp, Musculus pronator alæ.
o, Foramen præalare.
o_1, Foramen postalare.
pd, Processus dactyloformis.
pe, Pareposternum.
ptI, Processus pteralis thoracis I.
ptII, Processus pteralis thoracis II.
ptIV, Processus pteralis thoracis IV.
pt.A, Pterale A.
st, Stigma anterius.
st_1, Stigma posterius.

There its tendon is joined to the processus duplicatus of pterale A, while the tendon of the supinator alæ passes into the ligamentum anale.

5. *The supinator alæ primus* (text fig. 7, pl. 11, fig. 30, pl. 13, fig. 34; *msI*). This muscle is delta-shaped. It arises from the episternal pouch and passes into a tendon which, as mentioned above, is united with the tendon of the levator secundus. It passes beyond the pterale A_1, where the levator secundus is inserted, and into the anal ligament.

6. *The supinator alæ secundus* (text fig. 7, pl. 11, fig. 30; *msII*). This muscle is likewise delta-shaped. It arises at the apodema, behind the supinator primus, and is continued in a long tendon which traverses the foramen postalare, and is joined to the liga-

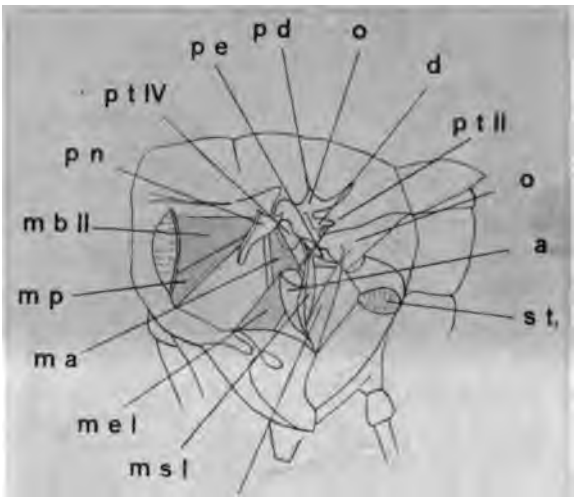


FIG. 7. Diagrammatic view of the direct muscles that lie more laterally. (Median section of the thorax.)

a, Mesapodema.
d, Processus duplicatus (Pterale A).
ma, Musculus anonymus.
mbII, Musculus abductor alæ secundus.
meI, Musculus levator alæ primus.
mp, Musculus pronator alæ.
msI, Musculus supinator alæ primus.
msII, Musculus supinator alæ secundus.
o, Foramen præalare.
o_1, Foramen postalare.
pd, Processus dactyloformis.
pe, Parepisternum.
pn, Parapterum.
ptII, Processus pteralis thoracis II.
ptIV, Processus pteralis thoracis IV.
st_1, Stigma posterius.

mentum anale near the processus pteralis thoracis VI and the processus alæ 4.

7. *The abductor alæ secundus* (text figs. 6, 7, pl. 11, fig. 30; *mbII*). This is the strongest of the direct muscles. It lies under

the abductor primus, is delta-shaped, arises from the rostral and ventral border of the parapleurum, and is continued in a tendon which extends under the parapterum, traverses the foramen postalare and is inserted on the anterior border of the wing-joint, probably close to the depression of the processus pteralis alæ 3. Lowne's view, that this muscle is attached to the parapterum, is erroneous.

8. *The pronator alæ* (text figs. 6, 7, pl. 11, fig. 30; *mp*). This muscle is similar in shape to the abductor secundus, but much more slender. It arises from the ventral border of the parapleurum, passes, together with the abductor secundus, below the parapterum, and is continued into a tendon which passes through the foramen præalare. Its insertion is similar to that of the abductor secundus. The exact spot of attachment could not be determined.

9. *The musculus gracilis* (text fig. 6, pl. 11, fig. 34; *mg*). This muscle is small and oval. It arises from the parapterum and is continued in a delicate tendon which is attached to the processus dactyloformis of the scutum.

10. *The musculus anonymus* (text figs. 6, 7, *ma*). As the name implies, I was unable to determine with certainty the points of insertion and the function of this muscle. It covers the episternum, is very delicate and appears to be somewhat rudimentary.

B. PHYSIOLOGICAL PART

Methods of Investigation

The experimental study of the movements of the wings is rendered difficult by the small size of the latter and by the complicated nature and rapidity of the former.

Three methods have been employed for investigating the nature of the wing-movement. The oldest of these is the optical method, which has been employed particularly by Pettigrew and by Marey (1886, p. 93). This method is based on making the tip of the wing especially visible by attaching to it a bit of gold leaf and then examining the bright line produced by this glittering point when the insect is held in a beam of strong light and induced to move its wings. The bright line then seen has the shape of the figure 8. Another method is the kymographic, which was likewise employed by Marey. When using this method the insect is held near a revolving blackened cylinder in such a manner that the moving tips of its wings describe points or curves on it. Since the tips of the wings move in spherical surfaces, they either—when the insect is

held far—touch the cylinder only at two points during each beat. or—when it is held closer—produce a curve so blurred that not much can be learned from it. On account of this, Marey's kymographic tracings do not show very much.

The third method is v. Lendenfeld's (1903) photographic method, by means of which series of instantaneous views of flying insects can be obtained (pl. 19, fig. 53).

The above statements show that the problem of applying the kymographic method to the study of insect flight had not been satisfactorily solved. I tried, therefore, to adapt that method better to this end by devising a new kind of flight-kymograph (pl. 14, figs. 35, 36). This consists of a wooden frame 120 cm. long and 20 cm. high. In grooves in the upper and lower parts of the frame there slides a thin board, 50 cm. long. This board can be rapidly shot from one end of the frame to the other by means of a steel spring. To this movable board is attached a horizontal groove, semi-circular in cross-section; the radius of the semi-circle being equal to the average length of a blow-fly's wing. In this groove a strip of glazed, blackened paper is fitted.

A fly in the normal horizontal position is held fast before the groove with the blackened paper so that the root of the wing lies at a point of the axis of the semi-cylindrical surface formed by it. When the fly attempts flight the tip of the wing touches the blackened paper. The stop holding the spring is then withdrawn, the board with its groove and blackened paper slides past the fly and the tip of the insect's wing describes a curve on the latter. Curves procured in this way are shown on plates 16, 17 and 18.

Flight

If the fly remains at the same place in the air (hovers), as is frequently observed among the Syrphidæ, each tip of the wing describes a figure 8. Although this fact was already known to Pettigrew, the general relations and the special peculiarities of this figure 8 have never been studied in detail. The tracings made with my flight kymograph (see above) show several things that had escaped the attention of Marey. In regard to the inclination of the 8 to the horizon, it was found that the long axis of the 8 is directed from above and behind, downward and forward,[1] and that

[1] The expressions upward, downward, forward, and backward are always used in relation to the body of the fly.

the angle this axis makes with the horizon varies between about 30 and 60 degrees. Also the direction (inclination) of the downstroke varies. The upper observed limit was 90 degrees. The lower loop of the 8 is, as already stated by Lowne (1890-1895, p. 204), considerably larger than the upper loop. I must remark, however, that I have never observed such an inclination of the 8 as Lowne describes, that indeed it would be contradictory to the observations I have made on the mechanism of the wing-beat described below. The direction of the wing-stroke is also incorrectly represented in Lowne's figure; von Lendenfeld's (1881, p. 368) accords better with my observations. As is incontestably shown in my kymographic curves (pl. 16, figs. 42, 43, 44), the movement of the wing whilst describing the lower curve of the 8 is, relative to the insect, a movement forward, and not, as Lowne says, a movement backward. The upper part of the 8, on the other hand, is described by the wing moving backward.

At rest the wings lie back upon the abdomen, projecting about a third of their length beyond it. When the insect wishes to fly it moves the wings (wing tips) somewhat forward,[1] and at the same time raises them. Then it makes a little jump and commences to describe the figure 8 with the wing tips. Both wings are expanded nearly horizontally and moved simultaneously almost vertically downward so that they press downward upon the air with their entire surface. The unsupported anal portion of the wing remains somewhat behind, because it cannot overcome the resistance of the air so easily as the strongly supported anterior portion. That the wings are held nearly horizontally during the downstroke (it being understood that the insect is flying horizontally) is clearly shown by the kymographic figures (pl. 15, fig. 41; pl. 16, figs. 42, 43, 44), particularly in the curves made by a wing, the tip of which had been nipped off. These curves are not described by a point (the tip of the wing), but by a line (the transverse section of the wing along which the tip had been cut off). During the downstroke this line described a broad band, or, since only the veins leave a distinct mark, two parallel lines corresponding to the only two veins, *IIaa* and *IIIba*, which extend so far toward the tip. Arrived below, the wing glides horizontally forward and then turns, the marginal vein being in front, upward and backward. In this phase the torsion of the wing is at its minimum. The anal border follows the path of

[1] See the chapter on the function of the muscles.

the marginal vein, so that in the kymographic figures (pl. 15, fig. 41; pl. 16, figs. 42, 43, 44) only a single tracing is visible. Arrived above the wing glides somewhat forward, not nearly so much, however as in the lower position, and with the marginal vein in front begins anew a downward stroke.

The modus operandi of this movement may be interpreted as follows: The downward movement is executed with great force while the surface of the wing lies nearly horizontal, only the anal marginal portion being bent slightly upward. The direction of this movement is nearly vertically downward, or downward and somewhat forward. There can be no doubt that the relief of the wing surface, the longitudinal folds and the hair increase the working pressure during the downstroke. The fly thus obtains during the downstroke a strong impulse upward, which overcomes its weight.

The great breadth of the lower loop of the 8 (pl. 15, fig. 41; pl. 16, figs. 42, 43, 44, 45; pl. 18, figs. 50, 51) shows that the wing moves upward much slower than downward. During this rather slow upstroke the wings become—if, as is usual, the insect flies forward—gliding surfaces, the fly glides forward, the slightest impulse to forward movement being sufficient to make the force of gravity effective for translation. At the same time the fly, of course, also slightly descends.

During the backward movement above mentioned the wing opposes only very little resistance to the air, but still enough to produce the necessary forward impulse. During this phase, also, there is descent. The upper horizontal movement backward is short in comparison with the lower forward one, and is in the main to be considered as the turning and adjustment necessary to make the wing ready for the next downstroke.

The rapidity of the forward progression chiefly depends on the angle of the long axis of the 8 with the horizon, and the insect flies fastest when the downstroke approaches a vertical direction. It can also be said that the progression is the slower the narrower the lower loop of the 8 becomes; and if it once becomes as narrow as the upper loop the beat of the wing will merely overcome the force of gravity and the insect will hover at the same spot, as the Syrphidæ so often do.

The Function of the Muscles and the Joints

The downward movement of the wing is caused by the contraction of the two powerful indirect dorsal muscles. Jurine (1820, p. 95)

describes an experiment proving this, which I have repeated in the following manner: From a recently killed fly whose wings are raised, the abdomen and head are removed and the thorax grasped in a broad forceps so that one of the points of the forceps is at its anterior, the other at its posterior end. On compressing the forceps the thorax is shortened just as it is when the dorsal muscle contracts. Thus the forceps' pressure imitates the action of the muscle, and a very slight pressure suffices to cause the wings to descend. The high development of the dorsal muscles readily explains the great force of the downward stroke of the wing.

That a contraction of the dorsal muscles must lead to a downward movement of the wings follows from a consideration of the anatomy of the skeleton. As the convexity of the back is increased by the contraction of these muscles, the processus præalaris (pl. 2, figs. 3, 4, *ptI*), as well as the processus postalaris (same figs., *ptII*), will be raised. By means of the processus postalaris the processus duplicatus of pterale A (pl. 3, fig. 8; pl. 4, fig. 9; *du*) is also raised, and the distal processes (processus rostralis and analis), acting as levers, correspondingly depressed. These processes then press the wings downward.

The dorso-ventral muscles act as antagonists to the dorsal. They compress the thorax in a vertical direction and accordingly act as raisers of the wings.

The function of the direct muscles was determined as far as possible under the binocular by pulling them with a fine forceps in the direction of their length. In this way the function of most of them could be made out quite clearly.

The adductor alæ (pl. 13, fig. 33, *md*) draws the wing backward toward the body. It serves to bring the wing back from the position of flight to that of rest.

The two abductors (pl. 11, fig. 30, *mbII;* pl. 13, fig. 33, *mbI*) draw the wing horizontally forward. One of these two muscles draws the wing when depressed and causes its forward movement during and after the downstroke.

The two levators (pl. 11, fig. 30; pl. 13, fig. 34, *meI, meII*) raise the wing, and at the same time draw it somewhat backward. Their action has a similar effect to that of the dorso-ventral muscles. They are inserted on the processus duplicatus of pterale A, and by their contraction depress that process and thus cause the wing to rise.

The two supinators depress the anal portion of the wing, and the pronator depresses its anterior border. By the action of these

muscles the torsion of the wing surface is produced and its degree changed as required. Apparently, in consequence of the action of the pronator, the torsion is increased during the downstroke.

The functions of the musculus anonymus and the musculus gracilis could not be ascertained.

Like von Lendenfeld (1884, opposed to Marey, 1886), I am of the opinion that the action of the direct musculature of the insect and not the resistance of the air chiefly causes the complicated changes in the shape and degree of torsion of the wings during their movement. The direct musculature serves also for steering. In several cases two muscles appear to perform nearly the same function. In these cases we may suppose that one of the two similar muscles is used in flight straight ahead, the second for steering. If the fly wishes to turn to the right or to the left it can, by means of the adductor, throw one wing back and by means of the abductor direct the other forward, and so turn the side of the contracted adductor.

A few additional remarks should be made about the wing-joint. Doubtless an important condition for good flight is absence of jerks and an elastic, unhindered, smooth movement of the wing. Independent of the elasticity of the materials, peculiar devices especially adapted for this purpose, make sure of the movement being of this kind. The processus pteralis thoracis IV, designated stroma (pl. 9, fig. 26, *ptIV*), which is a process of the episternum, occupies the axillary cavity of the wing, and is so situated that it comes to lie under the terminal portion of the remigium, the processus pteralis alæ 3 (pl. 9, fig. 26, *pt3*), during the downstroke. This piece, acting like an elastic cushion, probably mitigates the shock which might otherwise occur at the end of every downstroke.

The pterale C (pl. 9, fig. 26, *ptC*), that resembles an articular ball, and that fits into the socket of the processus pteralis alæ 3, may serve a similar purpose. It is to be mentioned concerning this that the pterale C is actually in the socket of processus pterale alæ 3 only when the wing is depressed. When the wing is raised, that ball and this socket are far apart. Pterale C may, therefore, also be considered as a sort of elastic buffer, serving to mitigate the shocks that might otherwise ensue at the ends of the wing-strokes.

The flexible zone also is a device serving this purpose. The broad wing of *Calliphora vomitoria* may, in view of the rapidity of the wing-beat, not be sufficiently elastic to permit an equable, unhindered movement. The hovering flies, whose wings are long and narrow,

and whose wing-veins are very delicate, have no devices of this kind to prevent jerks during flight. At every rapid change in the direction or velocity of the wing-movement considerable stresses must be produced, particularly in its basal part. The ill effects which these might otherwise have are avoided by the flexibility and elasticity of the wing which bends more or less at every stroke. If, as in the Syrphidæ, the wings are narrow and long, and the elasticity of the veins is sufficient to permit such bending, there is no special flexible zone. If, on the other hand, as in the blow-fly, the wing is short and broad and the veins are hard and inelastic, a special flexible zone is developed (pl. 6, figs. 18, 19, *si*). This view is supported by the serial instantaneous photographs made by von Lendenfeld (pl. 19, fig. 53), which show that just after the downstroke the distal portion of the wing is markedly bent.

It was not possible to ascertain the function of the curiously shaped processus pteralis thoracis V. Apparently this process can be interposed like a stop between pterale C and the socket of processus pterale alæ 3, and so hinder the buffer action of pterale C.

The processus pterale thoracis III as well as the processus pteralis thoracis I are articular connections. Parts of them are poor in chitin and therefore flexible, and they are firmly attached to the parts of the skeleton to which they belong.

I consider pterale B as a piece that serves to strengthen the joint. Like a clasp it aids in holding the upper and lower portion of the joint together.

The numerous small folds in the anal portion of the wing, already mentioned in the anatomical part of this paper, may serve to strengthen this region, which is but little supported by veins. This part of the wing is comparable to a Japanese paper fan, in which firmness is attained by radial folding.

IV. SYNOPSIS OF RESULTS

1. The constituents of the wing-joint can be divided into three morphological groups, quite distinct from each other:

1. The processus pterales thoracis.
2. The pteralia.
3. The processus pterales alæ.

2. The wing-joint is an exoskeletal structure, and therefore fundamentally different from the articular structures of vertebrate animals.

3. This difference is chiefly due to the fact that in insects the flexibility of the material permits some relative movement of differ-

ent parts of the same piece of chitin. The strong chitinous portions of the insect's joint continuously pass into thinner chitinous parts, which unite them with each other, while in vertebrates the different skeletal pieces are isolated and held together by muscles and tendinous structures only. The joints of insects have no capsules like those of vertebrates.

4. Similarities between the articulations of insects and vertebrates can, therefore, never be true homologies.

5. The complicated parts of the joint serve definite ends.

6. The pterale A raises and lowers the wing, working like a single-armed lever.

7. The pterale B strengthens the joint in a vertical direction.

8. The pterale C prevents or softens, like a buffer, the shocks at the end of each downstroke.

9. The processus pterale thoracis IV, the so-called stroma, has a similar function. It also contributes to softening the shocks or jerks of the wing-movement, particularly at the end of the up- and downstrokes.

10. There is in the wing a device, the flexible zone, which prevents the insufficient elasticity of the organ from being injurious.

11. The flexible zone renders possible a free, pendular vibration of the middle and distal parts of the wing at each reversal of the movement.

12. While the indirect muscles produce the elevation and depression of the wings, the direct muscles change the shape and position of the wings themselves, and the course they travel during each beat.

13. The direct muscles are probably also the steerers.

14. The downstroke of the wing is forward relative to the insect, and directed, in ordinary forward flight, downward and forward also relative to the surrounding air. It produces an elevation of the insect's body, which overcomes gravity but retards the forward movement.

15. During the horizontal movement of the wings, when depressed forward and also during the upstroke, the wings act as gliders, counteract gravity and retard horizontal advance, or vice versa. The fly descending glides forward, or ascending loses its horizontal velocity.

16. The torsion of the wing attains its maximum at the end of the downstroke, because its anal portion lags behind the anterior

part during the downstroke in consequence of its flexibility and the resistance of the air.

17. Toward the end of the upstroke the torsion is at its minimum.

18. The folds of the surface and the hairiness of the wing affect and probably heighten its mechanical effect on the air.

19. The numerous small folds of the anal portion of the wing, which is poor in veins, serve to strengthen it.

V. LITERATURE

ADOLPH, G. E.

1885. Die Dipterenflügel, ihr Schema und ihre Ableitung. Acta Ac. Leopoldina, Vol. 47, pp. 271-305, pls. 24-26.

AMANS, P.

1883. Essai sur le vol des insectes. Rev. Montpellier, Vol. 3, pp. 121-139, pls. 3, 4.

AUDOUIN, V.

1824. Recherches anatomiques sur le thorax des animaux articulés et celui des insectes hexapodes en particulier. Ann. sci. nat. Paris, Ser. 1, Vol. 1, pp. 97-135, 416-432.

BURMEISTER, H.

1832. Handbuch der Entomologie, Berlin. Allgemeine Entomologie, Vol. 1.

CHABRIER, J.

1822. Essai sur le vol des insectes et observations sur quelques parties de la mécanique des mouvements pogressives de l'homme et des animaux vertebrés. Paris, 328 pp., 18 pls.

HAMMOND, A. R.

1879. On the Thorax of the Blow-Fly (Musca vomitoria). Journ. Linn. Soc. London, Zoology, Vol. 15, pp. 9-31, pls. 1, 2.

JURINE, L.

1820. Observations sur les ailes des Hymenoptères. Mem. Accad. Torine, Vol. 24 (sc. fis.), pp. 172-240, 6 pls.

KIRBY, W., AND SPENCER, W.

1823-1833. An Introduction to Entomology or Elements of the natural history of insects, 4 Vols., London.

KLENKER, F.

1883. Ueber endoskelettale Bildungen bei Insekten. Göttingen, 53 pp.

KOLBE, H.

1893. Einführung in die Kenntnis der Insekten. Berlin.

KÜNCKEL D'HERCULAIS, J.

1875. Recherches sur l'organisation et le developpement des Volucelles, insectes diptères de la famille des Syrphides. Part I, Paris, 208 pp., pls. 1-11.

1877. Considerations sur le mécanisme du vol chez les insectes lépidoptères et hymenoptères. C. R. Soc. Biol. Paris, Ser. 6, Vol. 3, pp. 70-71.

1881. Recherches sur l'organisation et le developpement des Diptères et en particulier des Volucelles de la Famille des Syrphides. Part II, Paris, 1881, pls. 12-26.

LATREILLE, P. A.

1819. De la formation des ailes des insectes et de l'organisation exterieure de ces animaux, comparée, en divers points avec celles des Arachnides et des Crustacees. Mém. divers sujets histoire nat. Insectes, Paris, 44 pp.

LENDENFELD, R. v.
1881. Der Flug der Libellen. Sitz. Ber. Akad. Wien, Math. nat. Kl., Vol. 83, pp. 298-376, pls. 1-7.
1885. Notes on the flight of insects. Proc. Linn. Soc. New South Wales, Vol. 9, pp. 986, 987.
1885. On flight. Proc. Linn. Soc. New South Wales, Vol. 10, pp. 73-75.
1891. Notiz über die Muskulatur der Halteren. Zool. Anz., Vol. 14, p. 63.
1903. Beitrag zum Studium des Fluges der Insekten mit Hülfe der Momentphotographie. Biol. Centr., Vol. 23, pp. 227-232, 1 pl.

LOWNE, B. T.
1890-95. The Anatomy, Physiology, Morphology and Development of the Blow-Fly (Calliphora erythrocephala). A study in the comparative Anatomy and Morphology of Insects, London, 2 Vols., 350 pp., 21 pls., and 428 pp., 32 pls.

LUKS, C.
1883. Ueber die Brustmuskulatur der Insekten. Jena. Zeitschr., Vol. 16, pp. 529-552, pls. 22, 23.

MAREY, E. J.
1869. Mémoire sur le vol des insectes et des oiseaux. Ann. sci. nat. Paris, Ser. 5, Vol. 12, pp. 49-150.
1869a. Recherches sur la mécanisme du vol des insectes. Journ. Anat. Physiol., Vol. 6, pp. 19-36, 337-348.
1872. Second Mémoire sur le vol des insectes et des oiseaux. Ann. sci. nat. Paris, Ser. 5, Zool., Vol. 15, art. 13.

PETTIGREW, J. B.
1872. On the Physiology of Wings, being an analysis of the movement by which flight is produced in the insect, bat and bird. Trans. Roy. Soc. Edinburgh, 1871, Vol. 26, pp. 321-448.
1873. Animal locomotion; or walking, swimming, and flying. With a dissertation on aeronautics. London.

REDTENBACHER, J.
1886. Vergleichende Studien über das Flügelgeäder der Insekten. Ann. Hofmus, Wien, Vol. 1, p. 153-231, pl. 9-20.

STRAUSS-DÜRKHEIM, H. E.
1828. Considerations générales sur l'anatomie comparée des animaux articulés, auxquelles on a joint l'anatomie descriptive du Melolontha vulgaris (hanneton), donnée comme un exemple de l'organisation des Coléoptères. Paris, 19 pl.

VOSS, FR.
1905. Ueber den Thorax von Gryllus domesticus, mit besonderer Berücksichtigung des Flügelgelenks und dessen Bewegung. (Ein Beitrag zur Vergleichung der Anatomie und des Mechanismus des Insektenleibes, insbesondere des Flügels.) I-IV. Zeitschr. wiss. Zool., Vol. 78, pp. 268-354, 355-521, 697-759, 2 pl., 23 f.

WALTER, L.
1907. On the Clasping Organs Attaching the Hind to the Fore Wings in Hymenoptera. Smithsonian Miscell. Coll., Vol. 50, pp. 65-87, 4 pl.

[illegible]

[illegible] Plate 5

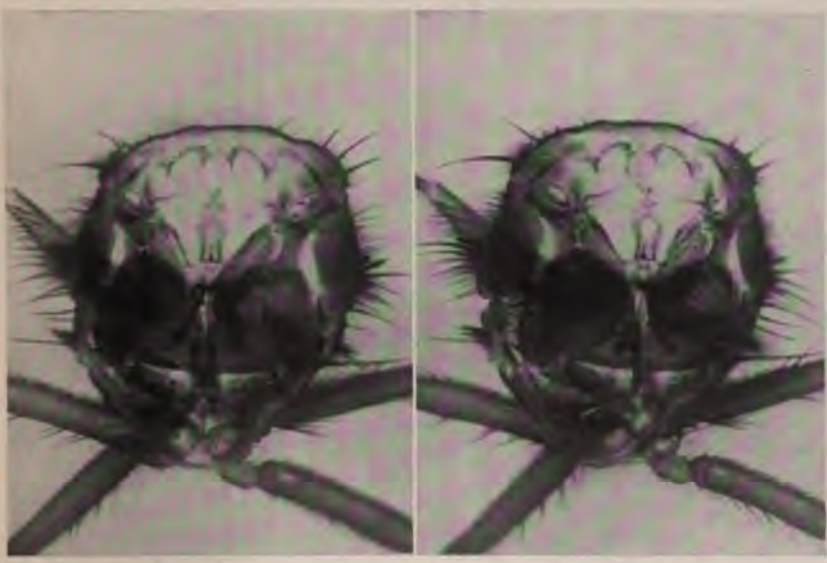
[illegible]

[illegible]

[illegible] Plate 5

[illegible]

1



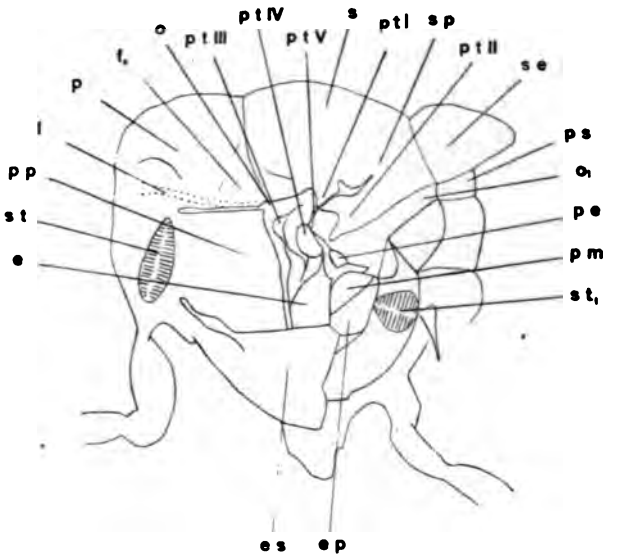
2

THORAX OF THE BLOW-FLY

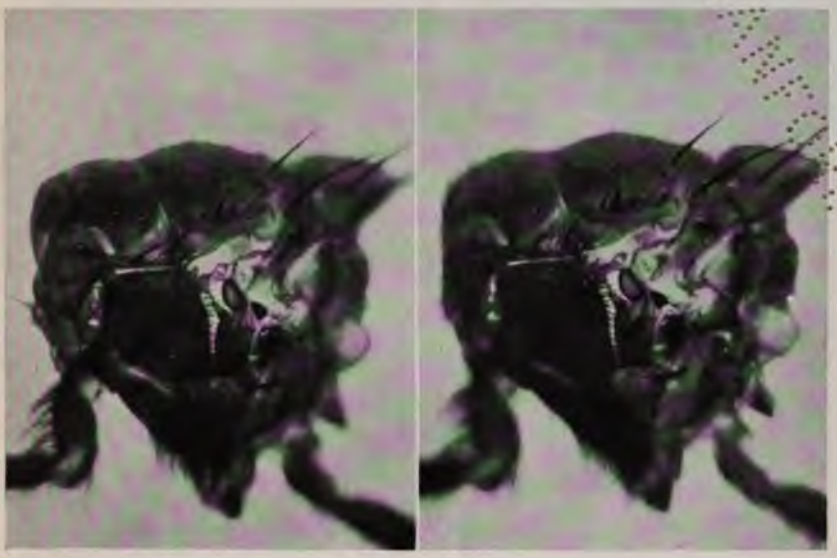
Digitized by Google

PLATE 2

FIG. 3. Stereoscopic view of the lateral wall of the thorax from without. (Magnified 10 diameters. Photographed with Zeiss binocular; Objective 55, Ocular 3.)



e, Episternum.
ep, Epimerum.
es, Mesosternum.
f_{11}, Fossa anterior.
l, Præscutal border.
o, Foramen præalare.
o_1, Foramen postalare.
p, Præscutum.
pe, Parepisternum.
pm, Parepimerum.
pp, Parapleurum.
ps, Postscutellum.
ptI, Processus pteralis thoracis I.
ptII, Processus pteralis thoracis II.
ptIII, Processus pteralis thoracis III.
ptIV, Processus pteralis thoracis IV.
ptV, Processus pteralis thoracis V.
s, Scutum.
se, Scutellum.
sp, Spina scutalis.
st, Stigma anterius.
st_1, Stigma posterius.



3

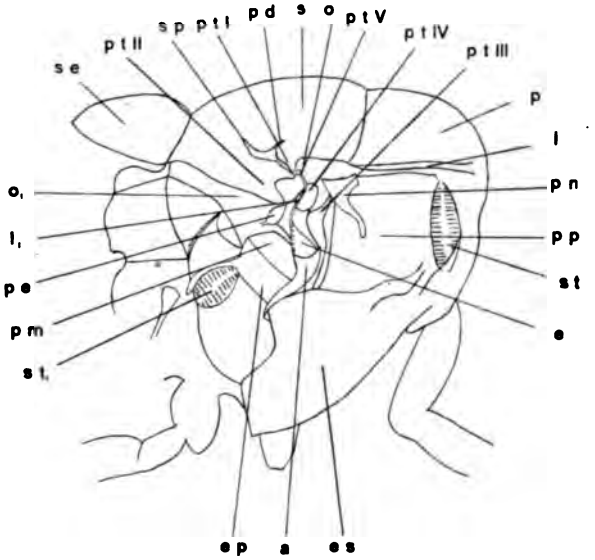
4

LATERAL WALL OF THORAX OF BLOW-FLY

STANFORD LIBRARIES

PLATE 2 (Continued)

FIG. 4. Stereoscopic view of the lateral wall of the thorax from within. (Magnified 10 diameters. Photographed with Zeiss binocular; Objective 55. Ocular, 3.)



a, Mesapodema.
e, Episternum.
ep, Epimerum.
es, Mesosternum.
l, Præscutal border.
l_1, Episternal border.
o, Foramen præalare.
o_1, Foramen postalare.
p, Præscutum.
pd, Processus dactyloformis.
pe, Parepisternum.
pm, Parepimerum.
pn, Parapterum.
pp, Parapleurum.
ptI, Processus pteralis thoracis I.
ptII, Processus pteralis thoracis II.
ptIII, Processus pteralis thoracis III.
ptIV, Processus pteralis thoracis IV.
ptV, Processus pteralis thoracis V.
s, Scutum.
se, Scutellum.
sp, Spina scutalis.
st, Stigma anterius.
st_1, Stigma posterius.

[illegible]

[illegible]

[illegible]

5

6

7

8

RIGHT WING AND PTERALE OF BLOW-FLY

SMITHSONIAN

PLATE 4A

FIG. 9. Pterale A. (Magnified 80 diameters. Photographed with Zeiss achromat A, Ocular 4.)

an, Processus analis. *ro*, Processus rostralis.
du, Processus duplicatus.

FIG. 10. Cross-section of the Mesothorax. (Magnified 10 diameters. Photographed with Zeiss achromat A, Ocular 2.)

dvII, Musculus dorso-ventralis secundus.
mm, Musculus dorsalis.

FIG. 11. Processus pteralis thoracis V. (Magnified 45 diameters. Photographed with Zeiss achromat A, Ocular 2.)

9

10

11

FLYING APPARATUS OF BLOW-FLY

SMITHSONIAN LIBRARIES

PLATE 4B

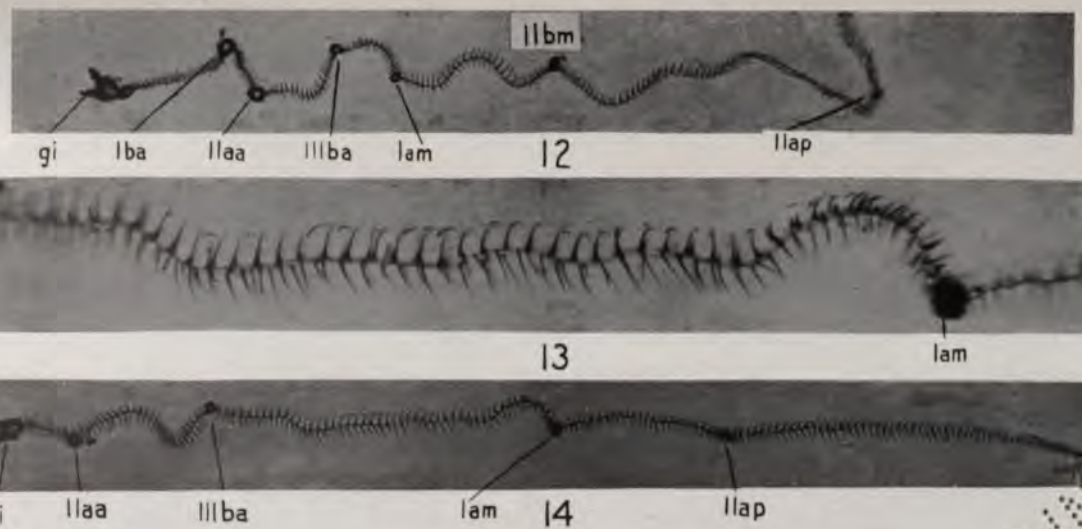
FIG. 12. Cross-section of the wing. (Magnified 30 diameters. Photographed with Zeiss achromat A.)

gi, Marginal vein.
Iba, Crest of first raised (convex) fold of the anterior region.
IIaa, Second depressed (concave) fold of the anterior region.
IIIba, Crest of third raised (convex) fold of the anterior region.
Iam, First depressed (concave) fold of the middle region, discoidal vein.
IIbm, Crest of second raised (convex) fold of the middle region.
IIap, Second depressed (concave) fold of the posterior region, anal vein.

FIG. 13. Part of a cross-section of the wing. (Magnified 100 diameters. Photographed with Zeiss achromat A, Ocular 6.)

FIG. 14. Cross-section of the wing. (Magnified 30 diameters. Photographed with Zeiss achromat A.)

gi, Marginal vein.
IIaa, Second depressed (concave) fold of the anterior region.
IIIba, Crest of third raised (convex) fold of the anterior region.
Iam, First depressed (concave) fold of the middle region, discoidal vein.
IIap, Second depressed (concave) fold of the posterior region, anal vein.



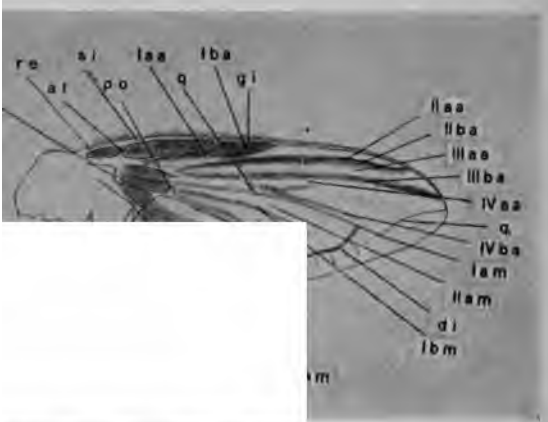
CROSS-SECTIONS OF WING OF BLOW-FLY

VOL. 59, NO. 12, PL. 48

Miami University

PLATE 5

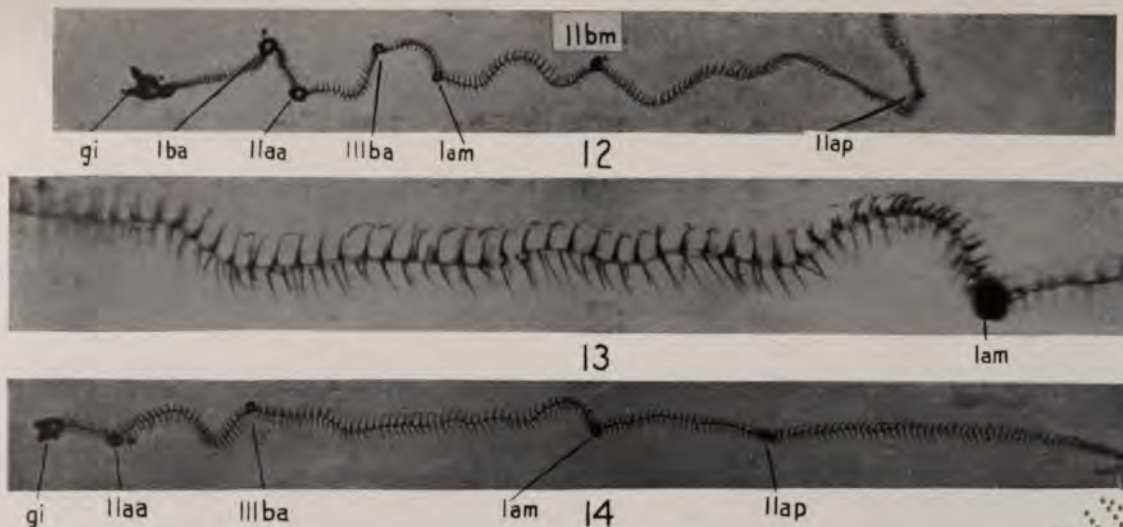
Fig. 15. Stereoscopic view of the right wing from above. (Dry preparation. **Magnified 4 diameters. Photographed with Zeiss binocular; Objective 55. Ocular 1.)**



Longitudinal folds (longitudinal veins):
***gi*, Anterior margin**, marginal vein.
***Iaa*, First depressed** (concave) fold of the anterior region, auxiliary vein.
***Iba*, First raised** (convex) fold of the anterior region, subcostal vein.
IIaa, Second depressed (concave) fold of the anterior region, radial vein.
IIba, Second raised (convex) fold of the anterior region.
IIIaa, Third depressed (concave) fold of the anterior region.
IIIba, Third raised (convex) fold of the anterior region, ulnar vein.
IVaa, Fourth depressed (concave) fold of the anterior region.
IVba, Fourth raised (convex) fold of the anterior region, spuria.
Iam, First depressed (concave) fold of the middle region, discoidal vein.
Ibm, First raised (convex) fold of the middle region.
IIam, Second depressed (concave) fold of the middle region, **division vein.**
IIbm, Second raised (convex) fold of the middle region, **submedian vein.**
IIIam, Third depressed (concave) fold of the middle region.
IIIbm, Third raised (convex) fold of the middle region.
Iap, First depressed (concave) fold of the posterior region, **anonyma.**
Ibp, First raised (convex) fold of the posterior region.
IIap, Second depressed (concave) fold of the posterior region, **anal vein.**
IIbp, Second raised (convex) fold of the posterior region, **axillary vein.**
IIIap, Third depressed (concave) fold of the posterior region.

Other parts:

aq, Transverse anal vein.
at, Anterior transverse vein.
di, Discoidal transverse vein.
fk, Knee of the wing.
lo, Lobulus.
po, Posterior transverse vein.
q, Median transverse vein.
q$_1$, Medio-marginal transverse **vein.**
re, Remigium.
si, Notch of the marginal vein in the flexible zone.
sq, Squamula.



CROSS-SECTIONS OF WING OF BLOW-FLY

SMITHSONIAN INSTITUTION LIBRARIES

Stanford University

PLATE 6

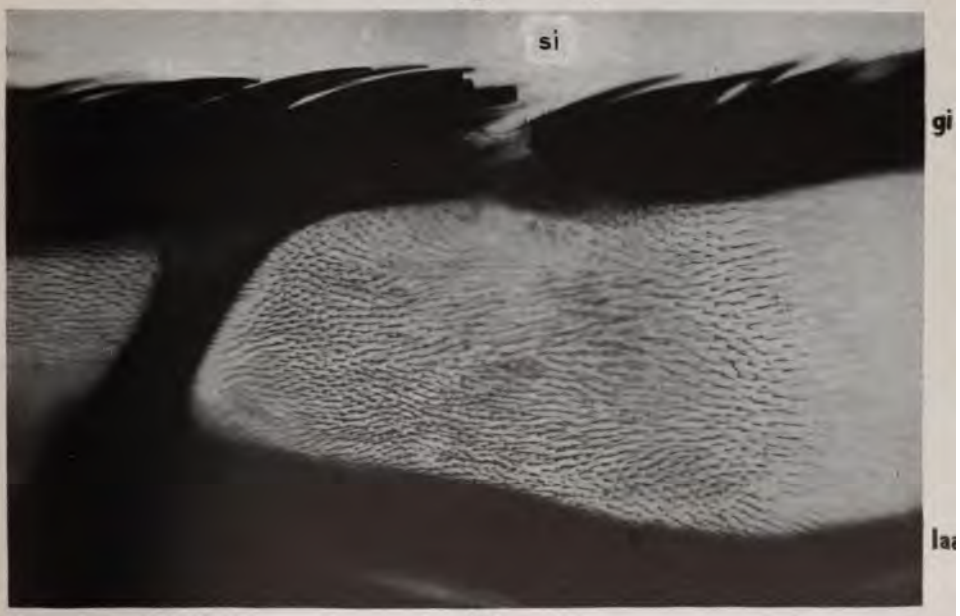
FIG. 18. Flexible zone. (Magnified 35 diameters. Photographed with Zeiss apochromat 16.)

gi, Marginal vein.
si, Notch.
Iaa, First depressed (concave) fold of the anterior region; auxiliary vein.
Iba, Crest of first raised (convex) fold of the anterior region.
IIaa, Second depressed (concave) fold of the anterior region.
IIIba, Crest of third raised (convex) fold of the anterior region.
Iam, First depressed (concave) fold of the middle region; discoidal vein.
IIbm, Crest of second raised (convex) fold of the middle region.
IIap, Second depressed (concave) fold of the posterior region; anal vein.

FIG. 19. Anterior portion of the flexible zone. (Magnified 120 diameters. Photographed with Zeiss apochromat 16, Ocular 6.)

Iaa, Auxiliary vein. *gi*, Marginal vein. *si*, Notch.

18 IIap



19

FLEXIBLE ZONE IN WING OF BLOW-FLY

PLATE 7

FIG. 20. The union of *IIaa* and *IIIba* in the flexible zone. (Magnified 350 diameters. Photographed with Zeiss achromat E, Ocular 2.)

FIG. 21. The union of *IIaa* and *IIIba* in the flexible zone. (Magnified 200 diameters. Photographed with Zeiss achromat E, Ocular 2.)

FIG. 22. The union of *IIaa* and *IIIba* in the flexible zone. (Magnified 100 diameters. Photographed with Zeiss apochromat 16, Ocular 6.)

20

21

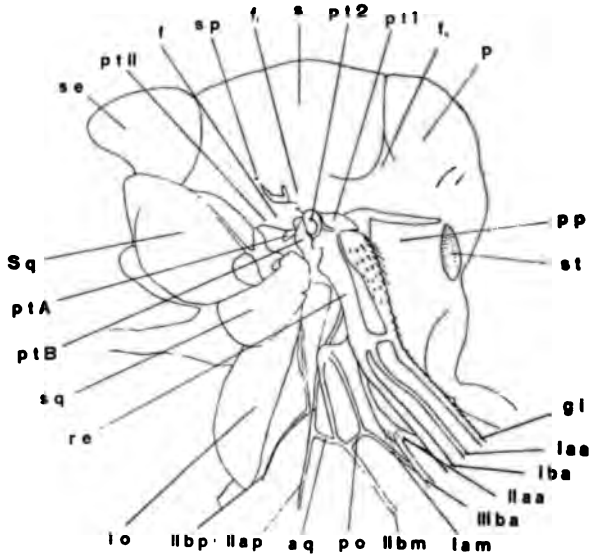
22

FLEXIBLE ZONE IN WING OF BLOW-FLY

Digitized by Google

PLATE 8

FIG. 23. Stereoscopic view of the side of the Thorax together with the wing-joint. (Magnified 10 diameters. Photographed with Zeiss binocular; Objective 55, Ocular 3.)



aq, Transverse anal vein.
f, Fossa postalaris.
f_1, Fossa præalaris.
f_{II}, Fossa anterior.
gi, Marginal vein.
lo, Lobulus.
p, Præscutum.
po, Posterior transverse vein.
pp, Parapleurum.
ptI, Processus pteralis alæ 1.
pt2, Processus pteralis alæ 2.
ptII, Processus pteralis thoracis II.
ptA, Pterale A.
ptB, Pterale B.
re, Remigium.
s, Scutum.
sc, Scutellum.
sp, Spina scutalis.
sq, Squamula.
Sq, Squama.
st, Stigma anterius.

Iaa, First depressed (concave) fold of the anterior region; auxiliary vein.
Iba, Crest of first raised (convex) fold of the anterior region.
IIaa, Second depressed (concave) fold of the anterior region.
IIIba, Crest of third raised (convex) fold of the anterior region.
Iam, First depressed (concave) fold of the middle region; discoidal vein.
IIbm, Crest of second raised (convex) fold of the middle region.
IIap, Second depressed (concave) fold of the posterior region; anal vein.
IIbp, Crest of second raised (convex) fold of the posterior region.

23

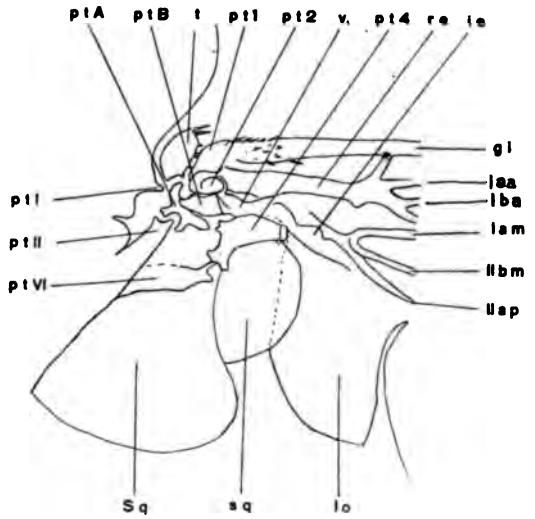
24

THORAX AND WING-JOINT OF BLOW-FLY

Property of Library

PLATE 8 (Continued)

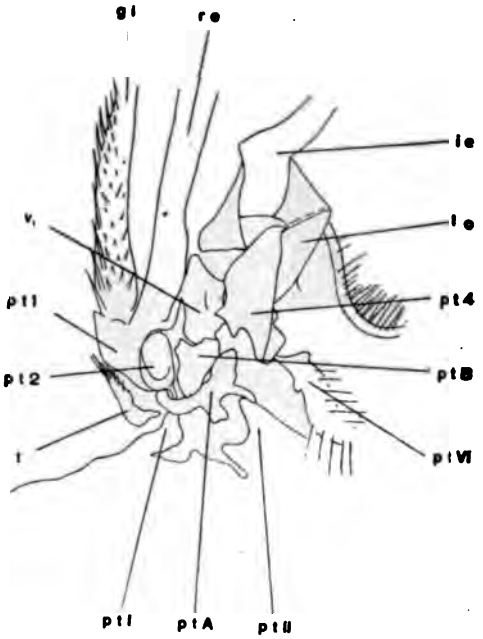
FIG. 24. Stereoscopic view of the right wing-joint from above. (Magnified 20 diameters. Photographed with Zeiss binocular; Objective a_2, Ocular 3.)



gi, Marginal vein.
ie, Vein of the inner margin of the lobulus.
lo, Lobulus.
pt1, Processus pteralis alæ 1.
pt2, Processus pteralis alæ 2.
pt4, Processus pteralis alæ 4.
ptI, Processus pteralis thoracis I.
ptII, Processus pteralis thoracis II.
ptVI, Processus pteralis thoracis VI.
ptA, Pterale A.
ptB, Pterale B.
re, Remigium.
sq, Squamula.
Sq, Squama.
t, Tegula.
v_1, Stay.
Iaa, First depressed (concave) fold of the anterior region, auxiliary vein.
Iba, Crest of first raised (convex) fold of the anterior region.
Iam, First depressed (concave) fold of the middle region, discoidal vein.
IIbm, Crest of second raised (convex) fold of the middle region.
IIap, Second depressed (concave) fold of the posterior region, anal vein.

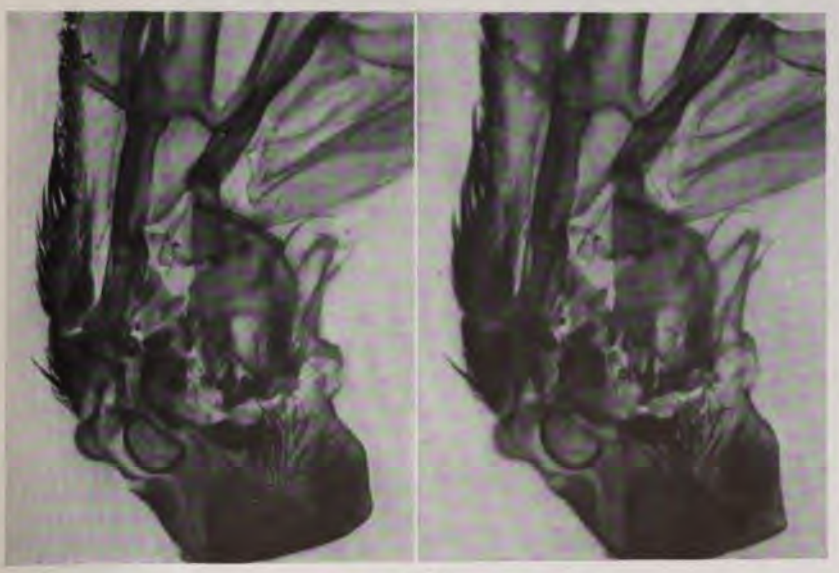
PLATE 9

FIG. 25. Stereoscopic view of the right wing-joint from above. (Magnified 40 diameters. Photographed with Zeiss binocular; Objective a$_4$, Ocular 3.)



gi, Marginal vein.
ie, Vein of the inner margin of the lobulus.
lo, Lobulus.
pt1, Processus pteralis alæ 1.
pt2, Processus pteralis alæ 2.
pt4, Processus pteralis alæ 4.
ptI, Processus pteralis thoracis I.
ptII, Processus pteralis thoracis II.
ptVI, Processus pteralis thoracis VI.
ptA, Pterale A.
ptB, Pterale B.
re, Remigium.
t, Tegula.
v_1, Stay.

25



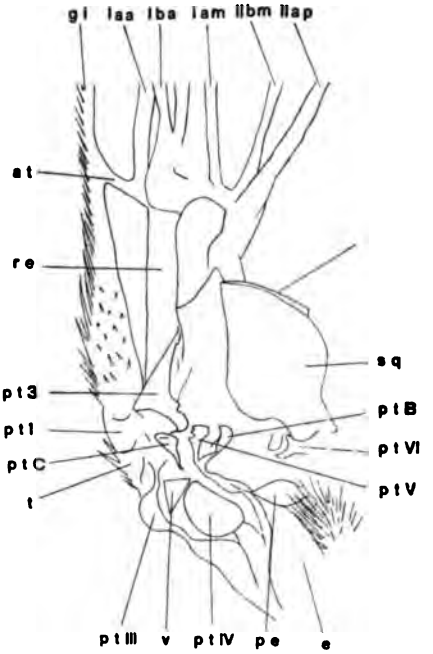
26

WING-JOINTS OF BLOW-FLY

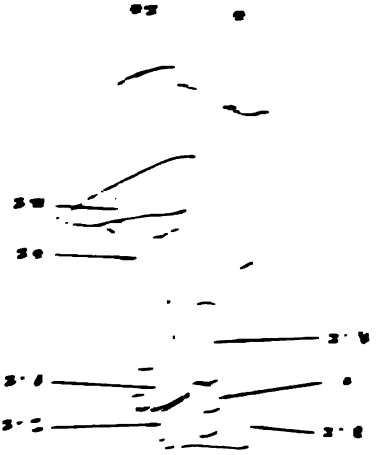
Digitized by Google

PLATE 9 (Continued)

FIG. 26. Stereoscopic view of the left wing-joint from below. (Magnified 40 diameters. Photographed with Zeiss binocular; Objective a_2, Ocular 3.)



at, Anterior transverse vein.
e, Episternum.
gi, Marginal vein.
pe, Parepisternum.
pt1, Processus pteralis alæ 1.
pt3, Processus pteralis alæ 3.
ptIII, Processus pteralis thoracis III.
ptIV, Processus pteralis thoracis IV.
ptV, Processus pteralis thoracis V.
ptVI, Processus pteralis thoracis VI.
ptB, Pterale B.
ptC, Pterale C.
re, Remigium.
sq, Squamula.
t, Tegula.
v, Stay.
Iaa, First depressed (concave) fold of the anterior region.
Iba, Crest of first raised (convex) fold of the anterior region.
Iam, First depressed (concave) fold of the middle region.
IIbm, Crest of second raised (convex) fold of the middle region.
IIap, Second depressed (concave) fold of the posterior region.



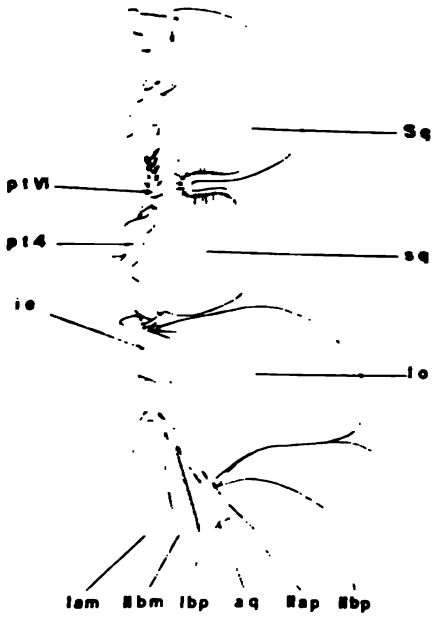
27

28

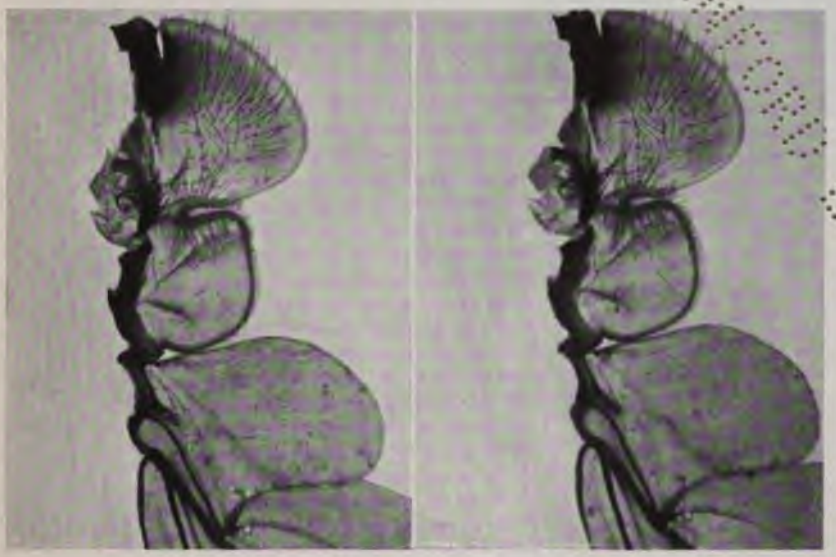
EPISTERNAL PROCESS OF BLOW-FLY

PLATE 11

FIG. 2. Stereoscopic view of the anal part of the wing-joint, from above. (Magnified 72 diameters. Photographed with Zeiss binocular: Objective 55, Ocular 3.



aq, Transverse anal vein.
le, Vein of the inner margin of the lobules.
lo, Lobules.
pt4, Processus pteralis alæ 4.
ptVI, Processus pteralis thoracis VI.
sq, Squamula.
Sq, Squama.
Iam, First depressed (concave) fold of the middle region, **discoidal vein.**
IIbm, Crest of second raised (convex) fold of the middle region.
Ibp, Crest of first raised (convex) fold of the posterior region.
IIap, Second depressed (concave) fold of the posterior region, **anal vein.**
IIbp, Crest of second raised (convex) fold of the posterior region, **axillary** vein



29

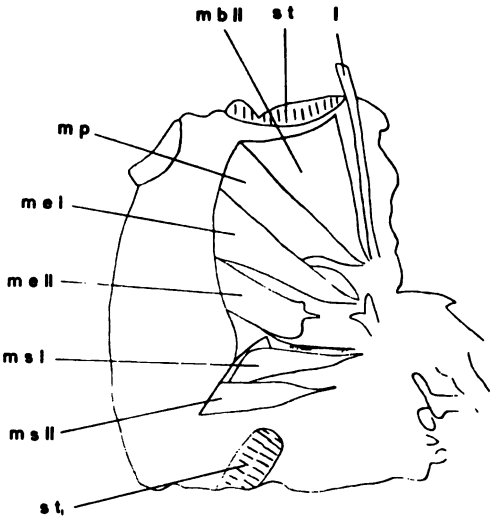
30

WING-JOINT AND MUSCLES OF FLIGHT OF BLOW-FLY

STANFORD LIBRARIES

PLATE 11 (Continued)

FIG. 30. Stereoscopic view of the most external (lateral) direct muscles of flight. (Magnified 20 diameters. Photographed with Zeiss binocular; Objective a_3, Ocular 3.)



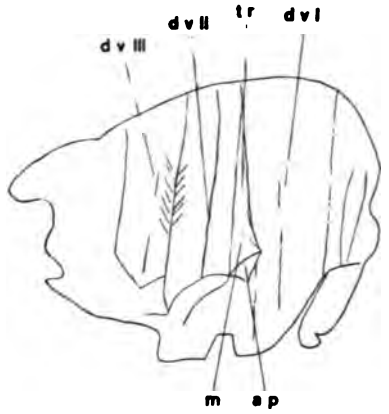
I, Præscutal border.
mbII, Musculus abductor alæ secundus.
meI, Musculus levator alæ primus.
meII, Musculus levator alæ secundus.
mp, Musculus pronator alæ.
msI, Musculus supinator alæ primus.
msII, Musculus supinator alæ secundus.
st, Stigma anterius.
st_1, Stigma posterius.

PLATE 12

FIG. 31. Stereoscopic view of the more medially situated indirect muscles of flight. (Magnified 10 diameters. Photographed with Zeiss binocular: Objective 55, Ocular 3.)

dvI, Musculus dorso-ventralis primus.
dvII, Musculus dorso-ventralis secundus.
lu, Air-sac.
m, Musculus latus.
mm, Musculus dorsalis.

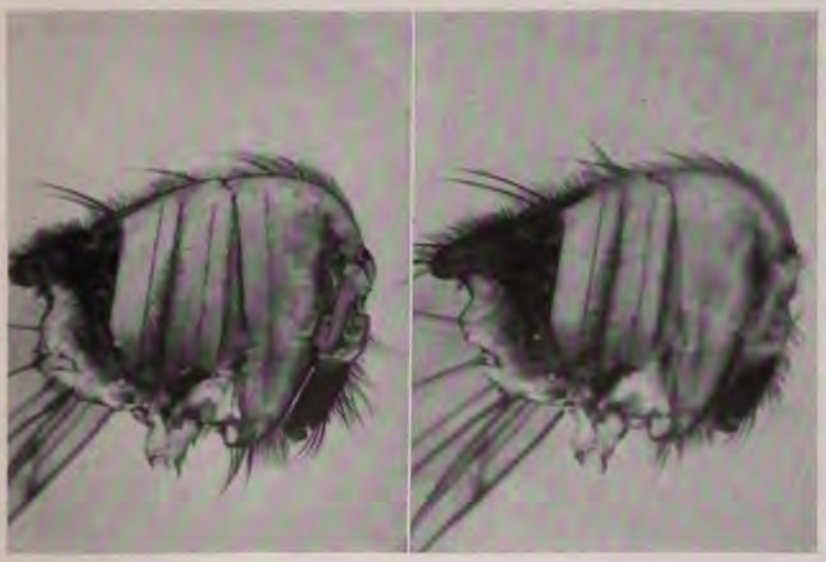
FIG. 32. Stereoscopic view of the more laterally situated indirect muscles of flight. (Magnified 10 diameters. Photographed with Zeiss binocular; Objective 55, Ocular 3.)



ap, Mesapophysis.
dvI, Musculus dorso-ventralis primus.
dvII, Musculus dorso-ventralis secundus.
dvIII, Musculus dorso-ventralis tertius.
m, Musculus latus.
tr, Trochanter muscle.

THE OHIO LIBRARIES

31



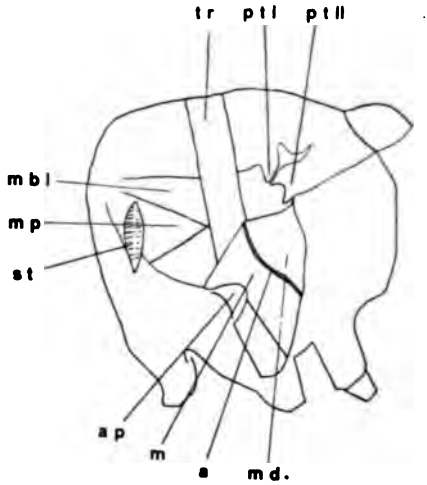
32

INDIRECT MUSCLES OF FLIGHT OF BLOW-FLY

Property of the Library
Wisconsin Historical Society

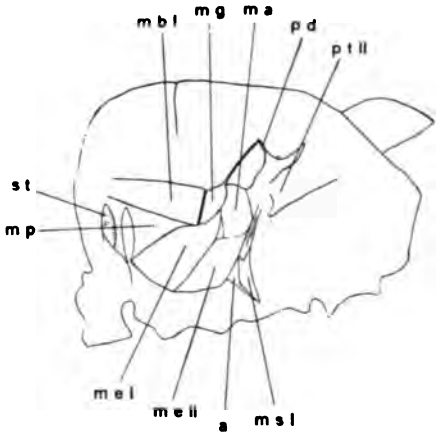
PLATE 13

FIG. 33. Stereoscopic view of the most internal direct muscles of flight. (Magnified 10 diameters. Photographed with Zeiss binocular; Objective 55, Ocular 3.)



a, Mesapodema.
ap, Mesapophysis.
m, Musculus latus.
mbI, Musculus abductor alæ primus.
md, Musculus adductor alæ.
mp, Musculus pronator alæ.
ptI, Processus pteralis thoracis I.
ptII, Processus pteralis thoracis II.
st, Stigma anterius.
tr, Trochanter muscle.

FIG. 34. Stereoscopic view of the intermediate direct muscles of flight. (Magnified 10 diameters. Photographed with Zeiss binocular; Objective 55, Ocular 3.)



a, Mesapodema.
ma, Musculus anonymus.
mbI, Musculus abductor alæ primus.
meI, Musculus levator primus.
meII, Musculus levator secundus.
mg, Musculus gracilis.
mp, Musculus pronator alæ.
msI, Musculus supinator alæ primus.
pd, Processus dactyloformis.
ptII, Processus pteralis thoracis II.
st, Stigma anterius.

PLATE 14

FIG. 35. Flight-kymograph ready for an experiment.

FIG. 36. Flight-kymograph after an experiment.

FIG. 37. The middle part of the apparatus represented in fig. 35, less reduced.

35

36

37

FLIGHT-KYMOGRAPH

Digitized by Google

PLATE 15

FIG. 38. Incomplete Flight-curve obtained by Marey's method on a blackened cylinder. (Natural size.)

FIGS. 39, 40. Incomplete Flight-curves obtained by Marey's method on a blackened cylinder. The cylinder was turned more slowly than in fig. 38, so that the parts of the curve overlap. The fly was held horizontally with the anterior end opposite to the direction of the movement of the cylinder. (Natural size.)

FIG. 41. Flight-curve obtained by means of the flight-kymograph. The fly was held horizontally with the anterior end opposite to the direction of the movement of the board. (Magnified 4 diameters.)

STANFORD UNIVERSITY

PLATE 16

FIGS. 42-45. Flight-curve obtained by the flight-kymograph. The fly was held horizontally with the anterior end opposite to the direction of the movement of the board. (Natural size.) Figs. 42-44 are consecutive parts of a continuous curve.

42

43

44

45

FLIGHT-CURVES OF BLOW-FLY

Digitized by Google

PLATE 17

FIGS. 46-49. Flight-curves obtained by the flight-kymograph. The fly was held horizontally with the anterior end in the same direction as the direction of the movement of the board. (Natural size.) Figs. 46-48 are consecutive parts of a continuous curve.

46

47

48

49

FLIGHT-CURVES OF BLOW-FLY

CAMBRIDGE UNIVERSITY LIBRARY

PLATE 18

FIGS. 50-52. Flight-curves obtained by the flight-kymograph. The fly was held horizontally with the anterior end opposite to the direction of the movement of the board. (Natural size.)

50

51

52

FLIGHT-CURVES OF BLOW-FLY

Property of Library

PLATE 19

FIG. 53. Series of instantaneous photographs of a flying *Calliphora vomitoria*. Direct sunlight. Time of exposure for each individual image 1/42,000 of a second. Interval between successive images 1/2,150 of a second. The arrows show the succession of time: the upper row running from right to left, the lower row from left to right.

Upper row (the fly seen from behind).

a, Lowest position of wings.

ab, Raising of the wings (the wing cross-sections are steep).

b, Highest position of wings.

bc, Depression of wings (the wing cross-sections are at first horizontal and then inclined).

c, Lowest position of wings.

Lower row (the fly seen from above).

d, Highest position of wings.

de, Depression of wings (the wing cross-sections are at first horizontal and then inclined).

e, Lowest position of wings.

ef, Raising of the wings (the wing cross-sections are steeply inclined, steepest in the middle of this phase of the movement).

f, Highest position of wings.

PHOTOGRAPH OF A FLYING BLOW-FLY

SMITHSONIAN LIBRARIES

Digitized by Google

SMITHSONIAN MISCELLANEOUS COLLECTIONS

VOLUME 56, NUMBER 13

TWO NEW AFRICAN RATELS

BY

N. HOLLISTER

Assitant Curator, Division of Mammals, U. S. National Museum

(PUBLICATION 1988)

CITY OF WASHINGTON

PUBLISHED BY THE SMITHSONIAN INSTITUTION

October 10, 1910

WASHINGTON, D. C.
PRESS OF JUDD & DETWEILER, INC.
1910

TWO NEW AFRICAN RATELS

By N. HOLLISTER

Assistant Curator, Division of Mammals, United States National Museum

Among some interesting Abyssinian mammals, collected and presented to the United States National Museum by the Hon. Hoffman Philip, minister resident and consul general, Adis Ababa, Abyssinia, is a specimen of *Mellivora* which clearly represents a form distinct from any heretofore described. While this specimen was being compared with the material in the Museum collection another undescribed species, represented by specimens from Mount Kilimanjaro and British East Africa, was discovered.

MELLIVORA ABYSSINICA, sp. nov.

Type from vicinity of Adis Ababa, Abyssinia. Cat. No. 171876, U. S. Nat. Mus. Old adult female, skin and skull. Collected in 1909 by Hoffman Philip.

General characters.—Size medium; mantle complete from between eyes to well on to tail; head and back of uniform color; white marginal line of mantle scarcely distinguishable.

Color.—Black, with a uniformly colored dark grizzled iron-gray mantle commencing in a point between the eyes, 45 mm. from nose, widening to ears, and extending in a large oval over entire back, tapering to a point again well out on base of tail. Entire black area with an inconspicuous sprinkling of white hairs. The gray mantle is made up of wholly black and wholly white hairs, and is sharply divided from the black of sides and underparts. A very faint marginal line of lighter gray is barely noticeable along sides of mantle. Width of mantle between shoulders, 115 mm.; at widest point, 175.

Skull.—The skull of the type is slightly damaged about the premaxillæ, and one zygomatic arch is broken, making it impossible to get accurate measurements of length or breadth. It is a very old adult and the teeth are much worn. The following measurements have been taken: Post-palatal length, 60; least interorbital breadth, 32.2; greatest breadth of brain-case, 68.5; length of mandi-

ble, 85; upper tooth row, including canine, 36.5; length of upper carnassial, 11.5; lower molar-premolar series, 32.7; length of lower molar, 13.8.

Measurements of dry skin.—Total length from nose to end of tail, exclusive of hairs, 960; length of tail, 145; length of longest claw, measured with dividers, 44.5.

Remarks.—This ratel is very different from the specimens of *Mellivora ratel* and *M. indica* in the National Museum. From a specimen of *M. ratel* from Cape Colony it most conspicuously differs in its smaller size and the indistinctness of the marginal lines along the mantle. From the descriptions of the type of *Mellivora concisa*[1] from Lake Chad it differs in the completeness of the dark iron-gray mantle, which is unbroken and uniform in color from a point well between the eyes to out on root of tail. It is apparently a slightly larger animal.

MELLIVORA SAGULATA, sp. nov.

Type from Mount Kilimanjaro, East Africa, at 5,000 feet altitude. Cat. No. 171875, U. S. Nat. Mus. Adult male, skin and skull. Collected September, 1889, by Dr. W. L. Abbott.

General characters.—A ratel of largest size with mantle complete from between eyes to tail. Differs conspicuously from *M. ratel* and *M. abyssinica* in the decided ochraceous color of the mantle.

Color.—Black, with a mantle of ochraceous tawny from between eyes to well out on base of tail, enclosing a much darker dorsal area. The mantle is pale ochraceous on forehead, darker tawny on nape and along margins; a darker grizzled blackish-brown center begins at neck, and, widening posteriorly, it completely obliterates the marginal line on hips and rump. Width of mantle between shoulders, 135 mm.; at widest point, 245.

Skull.—The measurements of the type skull slightly exceed all available measurements of *Mellivora* skulls.[2] Condylobasal length, 152; basal length, 140; palatal length, 71.5; post-palatal length, 70.5; zygomatic breadth, 87; least interorbital breadth, 32.4; upper tooth row, including canine, 44; length of upper carnassial, cingulum, 14.5; length of mandible, 98; lower molar-premolar series, 37.8; length of lower molar, 15.

---

[1] Thomas and Wroughton, Ann. and Mag. Nat. Hist., 1907, p. 376; Pocock, Proc. Zool. Soc. London, 1909, p. 398.

[2] The basal length of the very largest skull recorded by Welch (P. Z. S., 1909, p. 888), a male from Grahamstown, South Africa, is 135 mm.

Measurements of dry skin.—Total length from nose to end of tail, exclusive of hairs, 1220; length of tail, 210; length of longest claw, measured with dividers, 39.

Remarks.—The peculiar color of the back is the most striking character in comparing this form with *M. ratel* and *M. abyssinica,* the only neighboring species having the mantle complete from forehead to tail. It also appears to reach the maximum size. A second skin in the Museum collection, from British East Africa, exact locality unknown, agrees with the type in the large size and distinctive color of the back. Doctor Abbott has written on the label of the Kilimanjaro specimen, "Rare upon the mountain."

SMITHSONIAN MISCELLANEOUS COLLECTIONS

VOLUME 56, NUMBER 14

DESCRIPTIONS OF TEN NEW AFRIC BIRDS

BY

EDGAR A. MEARNS

Associate in Zoology, U. S. National Museum

(PUBLICATION 2003)

CITY OF WASHINGTON

PUBLISHED BY THE SMITHSONIAN INSTITUTION

December 23, 1910

WASHINGTON, D. C.
PRESS OF JUDD & DETWEILER, INC.
1910

DESCRIPTION OF TEN NEW AFRICAN BIRDS.

By EDGAR A. MEARNS

Associate in Zoology, United States National Museum

This paper is the eleventh dealing with the results of the Smithsonian African Expedition under the direction of Col. Theodore Roosevelt. It embraces descriptions of ten new species and subspecies of birds, eight of which were discovered by members of the Expedition.

Francolinus schuetti Cabanis is represented in East Africa by three slight but quite recognizable forms, from the Mount Kilimanjaro region, from the Mount Kenia region, and from the intervening Kapiti Plains, respectively. Specimens from each of these areas are quite uniform, and are described below.

FRANCOLINUS SCHUETTI MARANENSIS, new subspecies

Mount Kilimanjaro Francolin

Type-specimen.—Adult male. Cat. No. 117819, U. S. N. M. Collected at Maranu, Mount Kilimanjaro, German East Africa, altitude 5,000 feet, April 5, 1888, by Dr. W. L. Abbott.

Characters.—Similar to *Francolinus schuetti schuetti.* Crown sepia; feathers of back and scapulars dark brown, edged, except at tip, with pale gray, with chestnut shaft-streaks and coarse marginal black speckles; lower back, rump, and upper tail-coverts vandyke brown vermiculated with black; outer webs of outer primaries mottled and penciled with rusty brown; rectrices vandyke brown broadly banded with black; feathers of chest broccoli brown with broad apical shaft-stripes of prout's brown, without speckles; lower breast, upper abdomen, and flanks broccoli brown with darker brown centers to the feathers and narrow submarginal creamy white stripes.

Measurements of type (from skin).—Wing, 168 mm.; tail, 83; exposed culmen, 25.5; tarsus, 54; middle toe (without claw), 42.

Material.—Five specimens from Mount Kilimanjaro, German East Africa, collected by Dr. W. L. Abbott.

Remarks.—The juvenal plumage of this form has been described by Mr. Oberholser (Proc. U. S. Nat. Mus., vol. 28, 1905, p. 834).

FRANCOLINUS SCHUETTI KAPITENSIS, new subspecies

Kapiti Plains Francolin

Type-specimen.—Probably adult male (specimen not sexed). Cat. No. 213421, U. S. N. M. Collected at Juja Farm, near the Athi River, British East Africa, altitude about 4,200 feet, May 24, 1909, by J. Alden Loring. Original number, 111.

Characters.—Crown brownish olive mixed with gray; feathers of back and scapulars grayish hair brown mixed with black, broadly bordered with hair brown, without chestnut shaft-streaks or conspicuous marginal black spots; general color of lower back, rump, and upper tail-coverts olive-brown; outer webs of outer primaries plain dark brown; rectrices mars brown coarsely vermiculated with black; feathers of chest hair brown with narrow apical shaft-stripes of broccoli brown, thickly flecked with black near the shafts; lower breast, upper abdomen, and flanks hair brown dotted with black near the feather-shafts, and with broad creamy buff submarginal bands.

Measurements of type.—Wing, 167 mm.; tail, 85; exposed culmen, 26.5; tarsus, 51; middle toe (without claw), 41.

Material.—Three specimens from Juja Farm and Nairobi, British East Africa.

Remarks.—Two developed spurs on each tarsus, and its larger size, make it quite certain that the type is a male, as females usually lack developed spurs.

FRANCOLINUS SCHUETTI KENIENSIS, new subspecies

Mount Kenia Francolin

Type-specimen.—Adult male. Cat. No. 214739, U. S. N. M. Collected at Nyeri (altitude 5,943 feet), base of Mount Kenia, British East Africa, September 16, 1909, by Edgar A. Mearns. Original number, 16828.

Characters.—Crown bistre; feathers of back and scapulars bistre thickly vermiculated with black, and narrowly bordered with brownish gray finely mixed with blackish; lower back, rump, and upper tail-coverts bistre vermiculated with black; outer web of outer primaries plain dark brown; rectrices brown, finely vermiculated with black; feathers of chest hair brown with a large apical spot of sepia; lower breast, upper abdomen, and flanks sepia, the feathers broadly edged with buffy white penciled with sepia.

Measurements of type.—Wing, 175 mm.; tail, 84; exposed culmen, 27; tarsus, 49; middle toe (without claw), 40.

Material.—Three specimens from Nyeri and Wambugu, British East Africa.

NECTARINIA JOHNSTONI IDIUS, new subspecies

Mount Kenia Scarlet-tufted Malachite Sunbird

"*Nectarinia deckeni* Lorenz," HÖHNEL, narrative of Count Teleki's "Expedition to Lake Rudolf," English translation, vol. I, 1894, p. 374, note, *nomen nudum;* Ibis, 1894, p. 452.

Nectarinia johnstoni SHARPE, Bull. B. O. C. No. 12, 1893, p. ix (Mount Kenia).

Type-specimen.—Adult male. Cat. No. 215664, U. S. N. M. Collected on Mount Kenia at 14,000 feet, British East Africa, September 26, 1909, by Edgar A. Mearns. Original number, 16909.

Characters.—Similar to *Nectarinia johnstoni johnstoni* Shelley, but slightly larger; adult male with metallic feathers of upper parts more golden and less bluish green, this being exactly reversed in the coloration of the under parts; crissum more intense black. Adult female decidedly darker brown than the female of *Nectarinia johnstoni johnstoni.*

Measurements of type.—Adult male. Wing, 84 mm.; longest tail-feather, 215; culmen (chord), 31.5; tarsus, 19.

Comparative measurements.—Average of ten adult males of *Nectarinia johnstoni idius:* Wing, 82.6 mm.; longest tail-feather, 195.7; culmen (chord), 31.3; tarsus, 18.6.

Average of eight adult males of *Nectarinia johnstoni johnstoni* from Mount Kilimanjaro: Wing, 81.2; longest tail-feather, 175.9; culmen (chord), 30.9; tarsus, 17.7.

One adult male (Cat. No. 211929, U. S. N. M.) of *Nectarinia dartmouthi* from Mount Ruwenzori: Wing, 82.5; longest tail-feather, 175; culmen (chord), 26.2; tarsus, 19.5.

Average of seven adult females of *Nectarinia johnstoni idius:* Wing, 74.1; tail, 55.9; culmen (chord), 29.3; tarsus, 17.7.

Average of two adult females of *Nectarinia johnstoni johnstoni:* Wing, 72; tail, 52; culmen (chord), 29.2; tarsus, 16.8.

One adult female (Cat. No. 211986, U. S. N. M.) of *Nectarinia dartmouthi:* Wing, 73; tail, 55; culmen (chord), 26; tarsus, 19.

Remarks.—Males of this form require no comparison with *Nectarinia dartmouthi* Grant, but females resemble females of *dartmouthi* more than those of *johnstoni*, although they may be readily distinguished from the former by their longer bill and shorter tarsus.

CINNYRIS MEDIOCRIS KENIENSIS, new subspecies

Mount Kenia Double-collared Sunbird

Type-specimen.—Adult male. Cat. No. 215737, U. S. N. M. Collected at West Kenia Forest Station, 7,500 feet, British East Africa, September 19, 1909, by Edgar A. Mearns. Original number, 16865.

Characters.—Adult male similar to *Cinnyris mediocris mediocris* Shelley, but slightly larger, with metallic feathers of upper parts less golden green; red band across chest paler and more bricky red; lining of wings, and under parts posterior to red chest-band much paler, the latter more yellowish olive-green. Adult female with upper parts paler and more greenish olive-brown; under parts paler and yellower. In both sexes there is much more grayish white on the outer webs and tips of the outer tail-feathers.

Measurements of type.—Wing, 56 mm.; tail, 46.5; culmen (chord), 18.2; tarsus, 17.7.

Comparative measurements.—Average of ten adult males of *Cinnyris mediocris keniensis:* Wing, 55.1; tail, 48.4; culmen (chord), 18.7; tarsus, 17.6.

Average of nine adult male topotypes of *Cinnyris mediocris mediocris* Shelley: Wing, 52.3; tail, 45.7; culmen (chord), 18.4; tarsus, 17.5.

Adult female (Cat. No. 215733, U. S. N. M.) of *Cinnyris mediocris keniensis:* Wing, 50; tail, 40; culmen (chord), 17.5; tarsus, 17.5.

Adult female (Cat. No. 215733, U. S. N. M.) of *Cinnyris mediocris mediocris:* Wing, 46; tail, 37; culmen (chord), 17; tarsus, 17.

CYANOMITRA CHANGAMWENSIS, new species

Changamwe Olive Sunbird

Type-specimen.—Adult female. Cat. No. 215725, U. S. N. M. Collected at Changamwe (near Mombasa), British East Africa, November 25, 1909, by Edgar A. Mearns. Original number, 17587.

Characters.—Similar to *Cyanomitra olivacea ragazzii* (Salvadori), but much smaller, and paler on the under parts; upper parts olive green of the same shade as in *ragazzii;* under parts pale grayish pea green washed with yellow, most strongly on the throat and upper chest; pectoral plumes canary yellow; bill uniform brownish black.

Measurements of type.—Wing, 53 mm.; tail, 54; culmen (chord), 20; tarsus, 14.2.

Remarks.—A second female specimen (Cat. No. 215727, U. S N. M.) is albinistic. The upper parts are whitish drab, washed with yellow; under parts grayish white washed with yellow; bill and feet uniformly brown; wing, 52; tail, 41; culmen (chord), 19.7; tarsus, 13.5.

ANTHREPTES COLLARIS ELACHIOR, new subspecies

Lesser Collared Sunbird

Type-specimen.—Adult male. Cat. No. 215747, U. S. N. M. Collected at Changamwe (near Mombasa), British East Africa, November 25, 1909, by Edgar A. Mearns. Original number, 17593.

Characters.—Smaller and paler than *Anthreptes collaris zambesianus* (Shelley); upper metallic parts less coppery golden green; middle under parts canary instead of lemon yellow; outer webs of secondaries yellowish olive-green instead of bronzy yellowish green; sides paler and grayer.

Comparative measurements.—Average of six adult males of *Anthreptes collaris elachior* (five from Changamwe and one from Zanzibar): Wing, 46.7 mm.; tail, 35.8; culmen (chord), 13.7; tarsus, 14.3. Average of seven adult males of *Anthreptes collaris zambesianus* (from Taveta, Juja Farm, and Honi River (in the Mount Kenia district), British East Africa): Wing, 50.3; tail, 42; culmen (chord), 14.7; tarsus, 15.9.

Average of four adult female topotypes of *Anthreptes collaris elachior:* Wing, 45; tail, 33.5; culmen (chord), 13.3; tarsus, 14.5. Average of four adult females of *Anthreptes collaris zambesianus* from Taveta, British East Africa: Wing, 48.3; tail, 37.5; culmen (chord), 14.5; tarsus, 15.6.

Remarks.—An adult male (Cat. No. 148951, U. S. N. M.) from Zanzibar is so entirely similar to the Changamwe series that I have no hesitation in referring it to the present form.

PSEUDONIGRITA ARNAUDI KAPITENSIS, new subspecies

Kapiti Social-Weaver

Philetærus emini SHARPE, Ibis, 1891, p. 249 (Machakos).

Type-specimen.—Adult male. Cat. No. 213773, U. S. N. M. Collected at Juja Farm, Kapiti Plains, British East Africa, May 14, 1909, by Edgar A. Mearns. Original number, 15770.

Characters.—Differs from *Pseudonigrita arnaudi arnaudi* (Bonaparte) in being decidedly larger, with the colors paler throughout,

excepting the shoulder-patch, which has more black mixed with the gray.

Measurements of Pseudonigrita arnaudi kapitensis.—Adult male (type specimen): Wing, 68 mm.; tail, 41; culmen (chord), 14; tarsus, 18. Adult female (average of two topotypes): Wing, 65; tail, 40; culmen (chord), 14; tarsus, 18.

Measurements of Pseudonigrita arnaudi arnaudi (from Nimule, Lokko Zegga, and Ledgus, on the Upper Nile).—Adult male (average of four): Wing, 62.5; tail, 37.2; culmen (chord), 13; tarsus, 17.1. Adult female (average of five): Wing, 60.9; tail, 35.4; culmen (chord), 12.3; tarsus, 16.6.

Description of young (female; Cat. No. 213774, U. S. N. M.; killed at the same shot with the type).—Differs from the adult in having the crown hair brown like the upper side of the neck and upper back, conspicuously darker than rump and upper tail-coverts; lower back and scapulars blackish drab; shoulder-patch nearly black; black markings of wings and tail as in adults, but with narrow drab-gray tips to the wing-quills; secondaries edged externally with pale russet; bill dark brown above, flesh color on basal two-thirds of mandible, instead of black throughout; feet fleshy brown instead of light yellowish brown.

Material.—Three adults and one young from Juja Farm and Kamiti, British East Africa.

LAGONOSTICTA INCERTA, new species

Vinous Fire-finch

Type-specimen.—Adult male. Cat. No. 217311, U. S. N. M. Collected at Gondokoro, on the Bahr el Jebel, Uganda, Africa, February 25, 1910, by Edgar A. Mearns. Original number, 18805.

Description of type.—Crown, upper side of neck, back, and wings olive-brown perceptibly tinged with red; forehead in front of eyes, and entire side of head, including supraorbital stripe, and upper tail-coverts burnt carmine; tail black, bordered with carmine on outer webs of feathers at base; under wing-coverts pale buffy gray; under side of wing-quills dusky grayish; chin, throat, and breast vinaceous, fading to smoke gray on abdomen and grayish white on under tail-coverts; breast quite thickly spotted with white, tending to form bars; bill red, striped with black above, below, and along lower edge of maxilla; feet and claws brown.

Measurements of type.—Wing, 46 mm.; tail, 42; culmen (chord), 10.6; tarsus, 13.5.

SPOROPIPES FRONTALIS ABYSSINICUS, new subspecies

Abyssinian Speckled-fronted Weaver

Type-specimen.—Adult male. Cat. No. 100033, U. S. N. M. Collected by Blondeel in Abyssinia. Original number, 25845.

Characters.—Differs from *Sporopipes frontalis frontalis* in being larger and much paler in coloration; upper parts instead of ashy brown are pale ecru drab; wings and tail paler brown with broad whitish margins to the feathers; top and sides of neck paler cinnamon, with pale edging to the feathers; forehead and front of crown more brownish black, with broader white tips to the feathers; under parts almost white, with only the barest trace of a drab gray chest-band; under wing-coverts white.

Measurements of type specimen of Sporopipes frontalis abyssinicus: Wing, 65 mm.; tail, 52; culmen (chord), 12; tarsus, 19.

Average measurements of two adult males of Sporopipes frontalis frontalis (from Gondokoro, Uganda): Wing, 62; tail, 47.5; culmen (chord), 11.5; tarsus, 17.

SMITHSONIAN MISCELLANEOUS COLLECTIONS

VOLUME 56, NUMBER 15

NEW SPECIES OF INSECTIVORES FROM BRITISH EAST AFRICA, UGANDA, AND THE SUDAN

WITH ONE PLATE

BY

EDMUND HELLER

Naturalist, Smithsonian African Expedition

(PUBLICATION 2004)

CITY OF WASHINGTON

PUBLISHED BY THE SMITHSONIAN INSTITUTION

December 23, 1910

WASHINGTON, D. C.
PRESS OF JUDD & DETWEILER, INC.
1910

NEW SPECIES OF INSECTIVORES FROM BRITISH EAST AFRICA, UGANDA, AND THE SUDAN

(With One Plate)

By EDMUND HELLER

Naturalist, Smithsonian African Expedition

This paper contains descriptions of eleven new species and one new genus of *Insectivora*. The material described is from the collection made in east Equatorial Africa by the Smithsonian African Expedition under the direction of Col. Theodore Roosevelt. The bulk of the species are from Rhino Camp, in the Lado Enclave, Egyptian Sudan. The precise geographical position of this spot is latitude 2° 55′ north, on the west bank of the Nile, some fifteen miles north of the station of Wadelai.

This paper is the twelfth dealing with the results of the expedition.

ERINACEUS SOTIKÆ, new species

Sotik Hedgehog

Type from the Guaso Nyiro River, Sotik District, British East Africa; adult male; number 162112, U. S. Nat. Mus.; collected by J. Alden Loring, June 28, 1909; original number, 6451.

Characters.—Nasal bones very long and attenuate posteriorly, reaching to middle of frontal bones; zygomatic arches slender; spines with the dark point so minute that there is no visible terminal speckling to the coloration.

Coloration.—General dorsal coloration white, the spinous portion with a speckling due to the dark subterminal rings of the spines showing through. Snout, chin, lips, and head posteriorly to behind eyes, hair brown; fore and hind feet lighter brown; the legs white like the sides. Under parts white, the hair white to the base. Tail white. Dorsal spines annulated with a broad band of seal brown subterminally, the tip broadly white with a minute dark point. Low down on the sides a few wholly white spines are interspersed with the annulated ones. Longest spines on head 20 mm.

Measurements.—Head and body, 170 mm.; tail, 26; hind foot,[1] 25. Skull: condylo-incisive length, 42; zygomatic breadth, 27; nasals, 15.5 x 2.3; interorbital constriction, 11.2; palatal length, 25; breadth of palate, including first molar, 17; length of upper tooth-row, 21.8;[2] condylo-incisive length of mandible, 34.5.

This species is closely allied to *hindei* of Kitui in coloration and general proportions. It differs decisively in the greater length and attenuation of the nasal bones, the lighter zygomatic arches, and smaller skull. The type skull shows some asymetrical peculiarity. On the right side the premaxillary and frontal processes join and shut out the maxillary from the nasal, while on the left side these two bones are separated by the maxillary which borders the nasal for a length of 2 mm. There are four other specimens in the collection from the Sotik. These all agree with the type in the great length and attenuation of the nasals.

CROCIDURA SURURÆ, new species

Lado Giant Shrew

Type from Rhino Camp, Lado Enclave; adult male; number 164637, U. S. Nat. Mus.; collected by J. Alden Loring, January 18, 1910; original number, 8777.

Characters.—Smaller than *nyansæ*, but proportions the same; dorsal color lighter and grayer, without any brownish wash to the under parts.

Coloration.—Upper parts broccoli brown, merging gradually on sides to grayish, showing everywhere a grizzled effect, due to the grayish subterminal area of the hair showing through. Limbs whitish. Under parts grayish with a faint buffy wash. Lateral glands conspicuously marked by an oblong patch of short white hairs.

Measurements.—Head and body, 111 mm.; tail, 64; hind foot, 17. Skull: condylo-incisive length, 28.5; breadth of brain-case, 12; length of upper tooth-row, 13; condylo-incisive length of mandible, 18.

There are in the collection a series of nine specimens from the type locality. These are remarkably uniform in color and propor-

[1]All measurements of the hind foot given in this paper exclude the claws and were taken from the dried skins, which afford better means of comparison than the collector's flesh measurements.

[2]Some departure from the usual alveolar measurements of the tooth row has been made, the measurement as given throughout the paper being taken from the posterior end of the tooth row to the outside border of the central incisor. In the smaller species this measurement can be taken with greater preciseness than the alveolar length.

tions, which is a very unusual condition in the forms of this variable species. A single specimen from Gondokoro is referable to this form. It is, however, lighter than the Rhino Camp series, with longer tail, and no doubt represents the extreme in size and light coloration.

CROCIDURA MUTESÆ, new species

Uganda Large-toothed Shrew

Type from Kampala, Uganda; adult female; number 174636, U. S. Nat. Mus.; collected by J. Alden Loring, December 22, 1909; original number, 8430.

Characters.—Somewhat larger than *zaodon*, with much more brownish coloration.

Coloration.—Upper parts mummy brown, feet and tail darker seal brown; under parts grayish, with a wash of broccoli brown. Lateral glands marked by a narrow streak of short light brownish hairs.

Measurements.—Head and body, 115 mm.; tail, 64; foot, 16. Skull: condylo-incisive length, 25.5; breadth of brain-case, 11.2; upper tooth-row, 11.3; condylo-incisive length of mandible, 16.

Two other specimens from Uganda are in the collection, which are referable to this form. These are much darker, being seal brown in color, and very little larger than *zaodon*.

CROCIDURA NILOTICA, new species

Nile Swamp Shrew

Type from Rhino Camp, Lado Enclave; adult female; number 164638, U. S. Nat. Mus.; collected by J. Alden Loring, January 17, 1910; original number, 8768.

Characters.—Differs from *provocax*, its nearest ally, in its much shorter tail and pelage.

Coloration.—Upper parts dark clove brown; under parts slaty, but very little lighter than upper, but with a sepia wash. Feet, ears, and tail colored like the upper parts, except the long hairs of the latter, which are somewhat lighter brownish. Hair everywhere slaty at base. Hairs covering lateral glands uniform in color with those of sides. Hair short; length on rump, 5 mm.

Measurements.—Head and body, 92 mm.; tail, 48; hind foot, 14.5. Skull: condylo-incisive length, 23; breadth brain-case, 10; length tooth-row, 9.5; condylo-incisive length of mandible, 14.5.

There is in the collection a series of seven specimens from the type locality. They are quite uniform in coloration with the excep-

tion of two old adults, which show a few white flecks on the dorsal surface and much white spotting on the chin and throat. Besides the type series, there are in the collection a few specimens from Butiaba, Hoima, and Kabula Muliro, in Uganda.

CROCIDURA MAANJÆ, new species

Nyanza Brown Shrew

Type from Kabula Muliro; adult male; number 164639, U. S. Nat. Mus.; collected by J. Alden Loring, December 27, 1909; original number, 8502.

Characters.—Darker sepia above and purer gray below than *hildegardæ*, the under parts lacking the brownish wash; teeth heavier.

Coloration.—Upper parts, including limbs and tail, seal brown, merging gradually on the sides into the grayer under parts, which lack the brownish wash of the sides. Lateral glands conspicuously marked by an oblong patch of silvery white hair.

Measurements.—Head and body, 82 mm.; tail, 52; foot, 12.5. Skull (occipital region broken): breadth of brain-case, 8.7; length of tooth-row, 8.5; condylo-incisive length of mandible, 12.

The skull shows somewhat heavier dention than *hildegardæ* and the tooth-row is correspondingly greater.

Only a single specimen of this shrew is in the collection.

CROCIDURA LUTRELLA, new species

Enclave Veldt Shrew

Type from Rhino Camp, Lado Enclave; adult male; number 164640, U. S. Nat. Mus.; collected by J. Alden Loring, January 14, 1910; original number, 8729.

Characters.—Tail short and heavy; under parts light grayish buffy in marked contrast to the darker dorsal surface.

Coloration.—Upper surfaces of head, body, and tail light broccoli brown, this color descending on sides unchanged. Under parts and sides from level of mouth and under side of tail light grayish buff; sides of face nearly to level of eyes whitish. Hair everywhere light plumbeous at base. Feet whitish. Lateral glands large and conspicuously marked by a covering of silky white hair. Tail covered by scattered long white hairs throughout its whole length. Hair fairly dense, but short; length on back, 3 mm.

Measurements.—Head and body, 80 mm.; tail, 40; hind foot, 12. Skull: condylo-incisive length, 21; breadth of brain-case, 9.3; length of upper tooth-row, 9; condylo-incisive length of mandible, 12.3.

This species has the general appearance of *hindei,* but is much smaller, with the dorsal and neutral colors sharply marked and contrasted.

CROCIDURA PLANICEPS, new species

Flat-headed Shrew

Type from Rhino Camp, Lado Enclave; adult male; number 164641, U. S. Nat. Mus.; collected by J. Alden Loring, January 23, 1910; original number, 8837.

Characters.—Skull very different in shape from other Crocidura, the brain-case very flat, with a marked depression at its anterior termination in the interorbital region, the profile of the rostrum ascending slightly anterior to this depression; general body size of *hildegardæ.*

Coloration.—Above uniform seal brown, this color carried well down on sides, where it merges gradually into the lighter smoky gray of the under parts. Tail seal brown like the upper parts. Feet somewhat lighter brown than the back. Lateral glands distinctly marked by an oblong patch of whitish hair. Hair very short, only 2.5 mm. on rump, and uniform in color to the roots on upper parts. Hair of under surfaces, however, showing a narrow basal band of plumbeous.

Measurements.—Head and body, 71 mm.; tail, 53; hind foot, 12.3. Skull: condylo-incisive length, 18.3; breadth of brain-case, 8; length of upper tooth-row, 8; condylo-incisive length of mandible, 11.

This species in bodily size resembles *hildegardæ,* but it has decidedly smaller feet and skull, and darker coloration. From the *bicolor* group, of which *cuninghamei* is a form, it differs markedly in shape of skull, dark feet, and greater size. In skull characters it is quite distinct from any described species. The skull has somewhat the posterior elongation and narrowness of *Heliosorex,* but it is much less developed and not at all intermediate between this genus and *Crocidura.*

There are four other adult specimens from the type locality in the collection, and another from Hoima which possesses the skull characters of the species, but is somewhat smaller.

CROCIDURA LITTORALIS, new species

Butiaba Naked-tailed Shrew

Type from Butiaba, east shore of Albert Nyanza, Uganda; adult male; number 164642; U. S. Nat. Mus.; collected by J. Alden Loring, January 6, 1910; original number, 8598.

Characters.—Tail without longer hairs, as in *maurisca*, but much larger size than this species, with proportionately shorter tail.

Coloration.—Upper parts rich sepia, ears and feet somewhat lighter, tail darker blackish brown. Under parts vandyke brown, the chin and throat becoming suffused with grayish. Fur everywhere plumbeous at base; short, only 5 mm. on rump. Hair covering the lateral glands short, but not differentiated by color.

Measurements.—Head and body, 96 mm.; tail, 67; foot, 17. Skull: condylo-incisive length, 24; breadth of brain-case, 10; length of upper tooth-row, 10; condylo-incisive length of mandible, 14.3.

This species is one of the *maurisca* group, with a cylindrical, short-haired tail, the longer hairs being present only at the base.

HELIOSOREX, new genus

Type: *Heliosorex roosevelti* Heller

Characters.—Skull with the brain-case very much narrowed and marked by a prominent transverse constriction at its posterior third, well in advance of the lambdoidal crests; sides of interorbital region parallel; brain-case high and inflated, reaching its highest point midway between the constriction and its anterior end; dental formula as in *Crocidura;* first unicuspid about twice the size of second and third, which are of equal size; claws very small—about half the size of those of *Crocidura.*

The skull of this shrew differs more widely in shape from *Crocidura* than any other allied genus; in other words, it is the extreme in narrowness and posterior elongation. Some of the species of *Crocidura* show the constriction, but in all of these it is placed only slightly in advance of the lambdoidal crests, and the brain-case has, moreover, the triangular shape seen in typical *Crocidura.* The small claws are the only external character.

HELIOSOREX ROOSEVELTI, new species

Roosevelt Short-clawed Shrew

PLATE I.[1] Skull. Twice natural size

Type from Rhino Camp, Lado Enclave; adult female; number 109643, U. S. Nat. Mus.; collected by J. Alden Loring, January 21, 1910; original number, 8812.

[1] An unfortunate accident occurred to the skull after the two views shown on the plate had been taken. In adjusting the camera to take the side view the lens fell, striking the skull and damaging the occipital region to such an extent that further photographic work on the specimen had to be abandoned.

HELIOSOREX ROOSEVELTI HELLER

Type. Twice natural size

Digitized by the Internet Archive

Characters.—Skull very much narrowed, the brain-case narrow and high, with a marked contraction far in front of lambdoidal crests; claws very small; tail long, nearly equaling head and body.

Coloration.—Upper parts broccoli brown, sides slightly grayer; the color sharply marked from the buffy lower parts; under parts and lower sides buffy gray; chin, and sides of face to level of eyes, and feet whitish. Tail seal brown above, whitish below. Lateral glands marked by an oblong patch of silky white hair. Fur plumbeous at base; short, 4 mm. in length on rump.

Measurements.—Head and body, 85 mm.; tail, 66; foot, 14. Skull: condylo-incisive length, 21.5; breadth of brain-case, 8.5; length of upper tooth-row, 8.7; condylo-incisive length of mandible, 12.5.

The type is the only specimen in the collection.

I take much pleasure in naming this distinct type of shrew for Colonel Roosevelt, who took a keen personal interest in the collection of small mammals.

SYLVISOREX GEMMEUS, new species

Long-tailed Forest Shrew

Type from Rhino Camp, Lado Enclave, Egyptian Sudan; adult male; number 164644, U. S. Nat. Mus.; collected by J. Alden Loring, January 14, 1910; original number, 8730.

Characters.—Tail very long—much longer than head and body; lower parts of body pearl gray.

Coloration.—Color of upper parts, including limbs, seal brown, lower sides becoming slaty, the color encroaching much posteriorly on the gray of the lower parts, where only the median line of belly is light. Chin, throat, chest, and median line of belly pearly gray. Tail seal brown above, basal one-half lighter below. Under fur everywhere plumbeous.

Body rather thinly haired. Ears, limbs, and tail clothed with minute hairs, the latter without any longer hairs near its base, as in *Crocidura*. Length of hair on rump, 7 mm. Tail long and cylindrical, tapering very gradually.

Measurements.—Head and body, 69 mm.; tail, 72; hind foot, 15. Skull: condylo-incisive length, 18; breadth of brain-case, 8; length of upper tooth-row, 7.5; condylo-incisive length of mandible, 10.5.

The skull is the same general size as that of *mundus*, but differs in its greater length and narrowness, and is also somewhat flatter. The upper unicuspids show the same relative sizes.

There is one other specimen in the collection from Rhino Camp beside the type.

ELEPHANTULUS PHÆUS, new species

Masai Elephant Shrew

Type from Njoro O Solali, Sotik District, British East Africa; adult male; number 162074, U. S. Nat. Mus.; collected by J. Alden Loring, June 26, 1909; original number, 6441.

Characters.—Much darker dorsal coloration than in *pulcher* and with larger body size.

Coloration.—Above umber brown, lightly overlaid with black-tipped hairs; sides of body and head grayer and lacking the brownish; on the snout the gray color encroaching on the umber, which is confined to a median streak on the snout. Eye-ring white and continued posteriorly as a diagonal postocular stripe, bordered below by a dark-brown streak which breaks through the white eye-ring and reaches the eye. A fulvous patch behind each ear. Upper lip, under parts, and feet white, the white being sharply contrasted where it meets the tawny gray of the lower sides. Hair everywhere dark slate at base. Tail dark brown above, grayish below; the long hair of the rump lacking at the base of the tail, where a triangular naked area is exposed when the hair is disturbed.

Measurements.—Head and body, 133 mm.; tail, 133; hind foot, 33. Skull: condylo-incisive length, 36.5; zygomatic breadth, 20; nasals, 14; interorbital constriction, 6; length of palate, 18.8; length of upper tooth-row, 17.5; condylo-incisive length of mandible, 27; length of lower tooth-row, 15.5.

This form is closely allied to *pulcher*, from which it differs in the darker umber-brown color, being "gray-fawn" only on the sides. *Pulcher* is described as having the under fur of the under parts gray, and, if this is correct, *phæus* differs greatly in its dark slate under fur. The series of six topotypes in the collection is uniform in color with the type.

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 56, NUMBER 16

SOME RESULTS OF RECENT ANTHROPOLOGICAL EXPLORATION IN PERU

WITH FOUR PLATES

BY

DR. ALEŠ HRDLIČKA

Curator, Division of Physical Anthropology, U. S. National Museum

(PUBLICATION 2005)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
1911

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

SOME RESULTS OF RECENT ANTHROPOLOGICAL EXPLORATION IN PERU[1]

By Dr. ALEŠ HRDLIČKA,
Curator, Division of Physical Anthropology, U. S. National Museum

(With Four Plates)

Peru may well be regarded, even in its present territorial restriction, as the main key to the anthropology of South America. Due to the numbers of its ancient inhabitants, and to their far reaching social differentiations, indicating long occupancy, a good knowledge of the people of Peru from the earliest times is very desirable, and would constitute a solid basis from which it should be relatively easy to extend anthropological comparison to all the rest of the native peoples of the Southern Continent.

We know already, in a general way, that Peru, shortly before the conquest, was peopled by three or four larger "races" or strains of Indians: The Aymara (d'Orbigny) and the Quechua, in the central and southern highlands; the Huancas (Tschudi), in the north, and the Yungas (Calancha) or Chinchas (Tschudi), along the coast.[2] Besides this, a considerable number of unclassified tribes existed in the northeastern and northern regions of the great territory. These various peoples are known to have spoken a number of different

[1] Paper read before the Seventeenth International Congress of Americanists, City of Mexico, September, 1910, by Dr. Aleš Hrdlička, representative of Smithsonian Institution at Congress of Americanists at Buenos Aires, May 16 to 21, 1910, and at City of Mexico, September 7 to 14, 1910.

[2] Calancha, A. de. Chronica moralizada del Orden de San Augustin en el Peru, etc. 2 vols. Barcelona, 1639-1653.

Cieza, P. de. La Chronica del Peru. Sevilla, 1553. Anvers, 1554; English Transl., London, 1864-1883 (Hakluyt Soc. Pubs. Nos. 33 and 68).

Garcilasso de la Vega. Historia general del Peru. Cordova, 1616; London, 1688.

D'Orbigny, D. A. Voyage dans l'Amerique meridionale, etc. 9 vols., 4°. Paris, 1835-1847.

Rivero, E. de, and J. J. v. Tschudi. Antiguedades Peruanas. 4°. Vien, 1851; Transl. in English. 8°. New York, 1853.

Tschudi, J. J. v. On the Ancient Peruvians. 8°. London, 1884. Travels in Peru, etc. 8°. London, 1847.

languages and dialects and to have differed from each other in other respects, but their exact classification has not yet been determined, and from the standpoint of physical anthropology most of the groups are still enveloped in a haze of uncertainty.[1] Even ethnic units of such importance as the Quechua and Aymara are so little known physically that from the literature on the subject alone it would be impossible to form a clear notion as to their main characteristics.

The dearth of knowledge concerning the somatology of the peoples of Peru is due, on the one hand, to an almost complete lack of anthropological observations on the living, and, on the other hand, to the nature of the skeletal material which has thus far been collected. Not that the material is wanting, for there are many hundreds of Peruvian skulls scattered in our collections; but a very large majority of these skulls are more or less deformed, either artificially or accidentally, which renders them unsuitable for anthropological determinations, and other parts of the skeleton have been neglected. As to the skulls, there is no equally extensive territory in the world where cranial deformations, both intentional and unintentional, are as numerous as in Peru. Skulls of normal form from that country have actually thus far been rarities.

The accessions of Bolivian and Peruvian skeletal material in the principal American museums during the past few years have begun to shed more light on the physical characteristics of at least the Aymara and on a portion of the middle coast population of Peru. In consequence, it may be said to-day with comparative certainty that these two groups differ radically, at least so far as the cranial type is concerned; one (the Aymara) representing dolichocephalic, the other (middle coast) brachycephalic stock. Furthermore, we know to-day (due principally to Bandelier's collections) that the Aymara were in the main a people of relatively small stature, of only moderate muscular development, and often of rather small cranial capacity. The coast people from Ancon, Pachacamac, and one or two other localities, were also of rather low stature, but of somewhat stronger build, and had seemingly on the average a perceptibly larger skull. In both groups there was a relatively frequent occurrence of decidedly short and small-headed individuals. Beyond these few facts, however, things were problematical.

It was under these conditions that an opportunity, regrettably a

[1] For literature on the physical anthropology of Peru, see the end of this paper.

limited one, presented itself to the writer during the summer of 1910, to visit the Peruvian coast, and as the time at his disposal could not be extended, it was decided to visit the two most important districts on the coast, namely, Pachacamac, and Chan-chan or Gran Chimu. Due to exceptional circumstances, and to kind friends, especially Dr. Max Uhle, the Director of the Museo Nacional, at Lima, and Sr. D. Victor Larco Herrera of the valley of Chicama, and also to the courtesy of the Peruvian Government, it was not merely possible to make these visits with despatch, but with unlooked for results. The writer was enabled to examine over thirty separate cemeteries, and to gather upwards of 3400 crania, with a large quantity of other skeletal parts. And more fortunately still, a large percentage of the gathered skulls, particularly from the Chimu district, are free from artificial deformation, so that they will show clearly the cranial type of the people occupying and congregating in these regions.

With this material, and the available collections from Ancon and other localities of the Peruvian littoral, it will now be possible to learn definitely the physical characteristics of the population of the Peruvian coast for a distance of over 400 miles, and establish a firm foundation for anthropological comparisons for the rest of the country.

This report, preliminary to a detailed study of the collections, will give only the general results of the writer's observations.

The Pachacamac Region

The great ruins of the temples and city of Pachacamac are situated at the lower end of the valley of Lurin, about 18 miles south of Lima, whence they are reached part of the way by trolley and part horseback. The location is an exceptionally favored one scenically. It comprises a cluster of moderate barren elevations, in proximity to the ocean and its rocky islands toward the west, the highly picturesque, green, narrowing mountainous valley on the south and east, and the desert plain and elevations to the north. The ruins themselves are extensive, as well as impressive in character. They comprise not only remnants of two of the most important of the pre-Columbian Peruvian temples and those of an interesting "Inca" convent, but also an extensive, somewhat fortress-like central structure, and several complexes of habitations spreading over the hill and slopes toward the west and northwest of the principal portion of the ruins.

For a detailed history and description of Pachacamac, the writer must refer to the work of Dr. Uhle.[1] Pachacamac was a famous religious center, comparable to the Egyptian Thebes or the Mohammedan Mecca. It originally contained a shrine of the "creator" god, Pachacamac, to which flocked "pilgrims coming from all parts of Peru, three hundred leagues or more" (Estete), and later, after conquest of the place by the Peruvians of the highlands, it also had a famous Temple of the Sun. It was at the same time a political center, the seat of a chief who ruled over the populous valleys of Lurin, Rimac, Chancay, Huacho, Supe, and Huanan (Garcilasso). Its decline dates from the year of the entrance of the Spaniards (1533) and the destruction by them of the venerated statue of the principal deity of the place (Pachacamac). In the early fifties of the sixteenth century the Augustinian monks transferred the town to the valley, and in the first part of the seventeenth century it was already a desolate pile of ruins (Calancha).

The inhabitants and the pilgrims of Pachacamac disappeared, leaving scarcely a trace in history, but they left behind a vast number of graves. Uhle estimates the total number of burials that existed within and about the ruins at between 60,000 and 80,000. There are six or more aggregations of the graves which may be regarded as distinct cemeteries, but burials, often two deep, existed apparently in every available part of the ground, within the temples, and even about and within the dwellings. The middle part of the region, bounded by the principal ruins, and especially the front of the Temple of Pachacamac, look like one vast burial place.

These cemeteries, with the exception of a smaller one, heretofore unknown, found by the writer on the south side, have been for many years, in common with the majority of other burial places in Peru, the prey of the peons, engaged in searching for pottery and precious metals, which are carried to Lima for sale. Considerable and scientifically conducted work has been done here by Uhle, particularly in the neighborhood of the temples, but the area of depredations is much greater. The result of the peons' work is the destruction of thousands of mummy bundles, and often of the mummies themselves, scattering of the bones, damage to the walls and foundations, and destruction or abandonment of everything that cannot be sold with profit. The skulls, bones, wrappings, damaged fabrics, broken jars, etc., are left to litter the surface of

[1] Uhle, M. Pachacamac. University of Pennsylvania Publications, Folio, Philadelphia, 1903.

the sands or are but partly buried by the earth thrown out from the excavations. On the writer's arrival, the place looked like a veritable Golgotha, or some great barbaric battlefield, with skulls and bones whitening the ground and ruins in every direction.

In one sense, of course, these conditions, however they may be regretted, proved of great service, giving an invaluable opportunity for investigation and collection of skeletal material. It made possible the examination on the spot of several thousands of individual skulls, a good proportion of which, however, were not removed because of damage done by the shovel or the elements.

As to collecting the skeletal remains, the writer at first hesitated, because the place was the focus of pilgrimages from a large part of ancient Peru and doubtless the last resting place of numerous visitors from distant sections. But examination of the material soon revealed such a degree of anthropological uniformity, that it was decided to make as extensive a gathering as possible. In consequence, all the well-preserved crania and a large part of the long bones, besides other skeletal parts, were gradually transported to Lima and there packed, with Doctor Uhle's kind help and supervision, to be eventually shipped to Washington. The total collection from this locality (now safely housed in the U. S. National Museum) numbers over 2200 crania, and several thousands of other bones that are of special value for anthropological determinations.

It is not as yet possible to speak of the full scientific value of the collection, but it is not readily overestimated. A number of the more important points which presented themselves during the preliminary work in the cemeteries, are as follows:

It was seen first of all that the remains were derived partly from mummies, which were especially numerous in the neighborhood of the Temple of Pachacamac, and in part from simple burials; also, that in rare instances cremation had been practiced.

The mummies were not only artificial as to their exterior, but there appeared evidence that the bodies themselves, or at least some of their parts, had been specially treated; thus a number of skulls, for the most part such as were damaged by wounds, were found filled with cotton.

All the larger cemeteries contained burials of males, females, and even children, but the last were nowhere very numerous and were in a decided minority near the temples. Males and also a few adult and elderly females were collected from about the Temple of the Sun. On the southeast terrace of this temple, Uhle reports[1] finding

[1] Pachacamac, p. 84.

a burial place containing some 90 graves. Forty-six skulls were actually discovered. Objects unearthed with the burials showed pure Cuzco forms of culture. All persons interred in this cemetery were women, and none of these had died a natural death, but were victims of strangulation. All were adults; one of the skulls showed gray hair. It is probable that the victims were strangled as sacrifices to the deity of the temple.

The people buried at Pachacamac were in general of moderate stature and physical development, with shorter and weaker individuals not infrequent.

The crania belong very largely to the brachycephalic type. An unusually high percentage, for Peru, of the crania are free from deformation and show their type perfectly.

The majority of the skulls present either simple occipital, or a fronto-occipital artificial compression, either of which, however, was seldom extreme and such as to prevent the recognition of the real type of the skull. Deformed crania were particularly frequent in the large burial ground in front, that is north, of the old temple (that of Pachacamac).

Besides the more rounded skulls there were found, particularly in front of the old temple, some crania purely dolichocephalic. These were plainly strangers to the original population, visitors or invaders, in all probability part of the Inca Peruvians. The majority of these narrower skulls were without any deformation, while a few showed some occipital compression of accidental or cradleboard origin.

Absolutely no specimen was seen which presented the Aymara type of deformation, which shows that these highland people did not visit the Pachacamac temples, and were not among the conquerors of the place.

A number of submicrocephalic and even microcephalic but otherwise normal crania were found. They have nothing in common with the small skulls of our idiots.

Finally, the long and other bones were found to offer many features of interest, some of which will be touched upon before the conclusion of this paper.

CHAN-CHAN[1] (GRAND CHIMU)

The second region visited by the writer exceeds probably in importance even that of Pachacamac. This was the district of Tru-

[1] Term used among the local natives and probably more correct than "Chimu."

jillo, with the ruins and cemeteries of Moche, Chan-chan or Gran Chimu, and the extensive, shallow valley of the Chicama.

This region was the main seat of the powerful Chimu people and abounds in their remains, ruins, huacas,[1] and cemeteries. The cemeteries are particularly numerous in the valley of the Chicama, and it was there, at the Estancia Roma, with Señor Victor Larco, the owner of a large part of the valley and one of the most enlightened Peruvians, that the writer made his headquarters.

The valley of Chicama is a large plain, but little elevated above the sea level, traversed by a small river, the Chicama, and bounded on all sides except the west and the northwest, in an irregular and broken way, by hills and mountains. It is incompletely separated from the Chan-chan plain by a mass of hills known as Cerro de Cabra. Over its surface are several isolated rocky elevations, and toward the northwestward it connects with sandy flats which extend along the coast in the direction of Pacasmayo.

The valley shows only a limited number of ruins which, however, include an interesting and relatively well-preserved fortress. These are a short distance south of Chiquitoi, one of the haciendas belonging to Señor Larco. Besides this, however, numerous old huacas are situated southeast, west, and northwest of Chiquitoi, and, lining the bases of the hills within the valley or projecting into the same, as well as in the sands of the sea-shore, there are many cemeteries of the former native population.

The Chicama cemeteries, like those of Pachacamac, have fallen a prey to the greed of the peon, and of the collectors who incite and profit by the peon, with the result that a large portion of the burials, in some places even all, have been destroyed. And, as at Pachacamac so here, the skulls and bones, and such objects as could not well be sold, were left everywhere strewn over the surface of the ground.

In this region the writer was able to remain for nearly two weeks and through the generous aid of Señor Larco, who provided him freely with men, animals, and even the use of his local railroads, he was able to visit over 30 of the cemeteries, to make examination of their skeletal contents and to gather much of the better preserved material. The bones that passed through his hands in this valley amounted to many thousands of specimens, and the collections comprise over 1100 crania, all the skeletal parts from two of the largest cemeteries, and many additional specimens, particularly long bones, from other burials.

[1] Mounds, constructed in the main of sun-dried bricks.

Among the cemeteries seen were some quite extensive ones including hundreds of graves, while others were small, with only a few score of burials. In a few cases the cemeteries were confluent, but for the most part they were separated, though the distance between them in some instances was no more than a few yards.

The examination of the skeletal material and other objects made it evident that some of the cemeteries in this valley were more modern than others; that different cemeteries served for the burial places of different groups, clans, or tribes of people; and that in numerous instances late and even recent intrusive burials in small number have taken place in the old cemeteries.

It was possible further to determine that the huacas which dot the lower part of the valley were nothing but construction-cemeteries of the old coast inhabitants. They are burial mounds built of sun-dried brick and earth, instead of earth alone as usually.

Furthermore, higher in the valley, the cemeteries were evidently those of the agricultural populations of the region, while along the coast they were those of fishermen.

The burials were for the most part simple, the body being laid in the ground wrapped in a blanket. More elaborate mummy-bundles, however, were occasionally encountered, but nothing was seen or learned that would point to intentional mummification of the body or any of its parts, as at Pachacamac. In rare instances, also, there was cremation.

As at Pachacamac, so here, too, burials in the contracted position were the rule.

An indisputable fact, applicable to all the Chicama cemeteries, is the relative scarcity of the remains of children. This is not due to the earlier decay of children's bones, for where such were found they were in just as good condition as those of the adults. It indicates either a general scarcity of children, separated interments, or a low infant mortality.

Besides the Chicama valley cemeteries, there were examined that of the Cerro de Virgen, near Chan-chan, as well as that about the Huaca of the Moon near Moche; and skeletal material was seen and in a small part collected from Chan-chan (Gran Chimu) itself.

The large cemetery about the Cerro de Virgen, was found to be a general burial ground for men and women, but there were seen no bones of children. The Huaca of the Moon appears to be mainly, if not entirely, an immense and archeologically important burial mound, built from sun-dried brick.

From the standpoint of physical anthropology, the examination of the skeletal material from the cemeteries in the district of Chiquitoi, and in the rest of the valley of Chicama, proved exceedingly interesting, for the majority of the people were found to have been of exactly the same type as those of the region of Pachacamac, that is, moderate in stature and brachycephalic.

However, it also became evident that the valley of Chicama was peopled, in the course of time, by more than one tribe of natives, though all or nearly all such tribes belonged probably to the same original stock. In some of the cemeteries were found only the undeformed and brachycephalic skulls, with those showing the accidental occipital flattening. In others there were a great preponderance of crania with highly developed occipital flattening and, mixed with these, were individuals with the fronto-occipital, or "flathead," intentional deformation. Finally, besides all these, and as at Pachacamac, there were encountered now and then individuals, or little groups of burials, with the dolichocephalic cranial type. The skulls of these were undeformed, or merely accidentally flattened in the occiput.

The more modern nature of some of the cemeteries and burials was shown especially by the pottery. In two examples in particular a vessel was seen which represented clearly conditions known only after the Spanish invasion.

There was again not a single skull which presented the Aymara type of deformation. It is certain that the Aymara proper did not reach either this valley or Pachacamac, either as pilgrims or as settlers after the conquering Incas. Squier mentions[1] having seen some skulls with the Aymara deformation, possibly the remains of soldiers, about the "Castillo" at Chan-chan, but the many ordinary cemeteries examined by the writer failed to show any such instances.

One or two facts were learned of special interest to archeology. Although only very limited excavations were undertaken, it was nevertheless possible to observe an association of certain types of pottery with definite types of people; and there is also a strong probability that differences in pottery existed at different periods of occupation of the valley. In general, the huacas and cemeteries near the sea and belonging to the original people of the valley, the old coast brachycephals, show pottery of simpler forms and more sombre colors than that found in some of the more inland burial

[1] Squier, E. G. Peru. 8°. New York. 1877, p. 123.

grounds. The ware also reminds one of some of the more northern types (pls. 1, 3, and 4).

In several of the more inland cemeteries, on the other hand, the differentiation of form in pottery and also its fineness have reached a high level. Finally, graves which appear to be more modern yield especially vessels with large, flaring borders characteristically decorated in red with various figures, some of which represent natural objects, as animals, warriors, etc., while others are apparently of complex symbolic meaning. Two graves, which yielded undeformed dolichocephalic skulls, contained highly ornamented pottery which probably belongs to the last mentioned period (pl. 2).

Conclusions

Although the detailed study of the large series of specimens collected about Pachacamac and in the district of Trujillo will undoubtedly bring out numerous points which can scarcely as yet be foreseen, it is nevertheless possible from the preliminary examination of the material to state certain important facts bearing on the anthropology of the people represented by the collections.

In the first place, it can now be positively stated that the whole coast of Peru, at least from Pisco, well south of Pachacamac, to Pacasmayo, north of the valley of Chicama, was peopled by one and the same type of natives, the brachycephalic Indian of moderate stature. This bears out to a large extent the statement of Calancha (Vol. 2, chap. 29), that "the people of the coast, the Yungas, the dwellers of the plain and of the sandy desert, extended over all the district from Piura to Arica, 300 leagues in length and from 12 to 15 in breadth, according to the width of the coast land."

Chronologically, the earliest people in these regions were evidently those whose remains are found in the huacas and in some of the cemeteries where the pottery is of simpler, though often interesting forms. In these cemeteries metal is scarce and is principally gold.

These people were followed by others of the same fundamental physical type, but of modified habits, shown in part by the pronounced occipital head flattenings, which indicates the use of cradleboards to which the infant was tied for a prolonged period, and especially in the frequent practice of the intentional fronto-occipital skull deformation. These deformations represent apparently a change of habits with the times, or the immigration of people with such customs, rather than a manifestation of caste, though this may not have been without influence. Belonging to this period are large

TWO BOWLS FROM AN ANCIENT HUACA, NEAR THE HACIENDA CHIQUITOY, IN THE VALLEY OF CHICAMA. THE HUACA YIELDED ONLY BRACHYCEPHALIC SKULLS OF THE ORIGINAL CHIMU POPULATION (GREATEST BREADTH OF RIM, UPPER VESSEL 17.6 CM., LOWER 18.8 CM.)

DIGITIZED BY Google

cemeteries, in which the graves yield copper or bronze, with some gold, besides the before mentioned interesting pottery.

At about the time of the greatest prevalence of the deformed crania, there appear individual elements of the dolichocephalic type of the Indian. These are not local developments, for intermediary cranial forms, which in that case would be numerous, are lacking. Nor are they the Aymara who, though dolichocephalic, have since early Tiahuanaco times practiced the peculiar circular head deformation which now bears their name. It seems most probable that these dolichocephals came with or after the invading forces of the central or highland Peruvians and represent some of the more eastern or northern tribes of Peru. It was from the graves of such individuals that the writer obtained the ornamented pottery, shown in pl. 2, which is very distinct from any that occur in the old huacas and the coast burials.

The brachycephalic people seem to have been the first inhabitants of the coast, for there was absolutely no trace of any previous occupants; and the peopling of the coast by the brachycephals, judging from the nature and extent of the cemeteries, could not have been of any very great duration, not over some centuries before the arrival of the whites.

This old type of the coast people is fundamentally the same as a large portion of the inhabitants of Equador, Colombia, Panama, Central America, and Yucatan. The present native population was seen by the writer to show this type as far as the southern confines of the Peru of to-day. Farther southward, however, at Arica and along the Chilean coast, there is found an increasingly large proportion of dolichocephalic natives, and from the northern extremity of the central part of the Chilean coast southward this latter type is the only one encountered.

The preliminary examination of the skeletal material at Pachacamac and in the valley of Chicama has brought forth also some interesting evidence of medical nature.

There was not a single instance of rachitis.[1] In only one case (Chicama) was there seen a vertebra that may have been tuberculous, but the evidence was not entirely conclusive and the age of the grave was unknown. Only two burials were encountered in which the bones were surely syphilitic; but both of these graves were among the more recent, in all probability post-Columbian. Besides

[1] For comparison, see the writer's Physiological and Medical Observations, Bulletin 34, Bureau of American Ethnology, Washington, 1908.

these, there were collected about thirty long bones with more or less marked inflammatory alterations, which may be syphilitic, but the diagnosis cannot be made with certainty. A very large majority of the many thousands of long bones collected or examined showed no lesions whatever. With two uncertain exceptions no single skull out of the 3400 brought away, and the many additional ones that were looked over, presented a case of ulceration or a lesion which could be with confidence attributed to syphilis.

In the Chicama cemeteries, and to some lesser extent in those of Pachacamac, there was a marked rarity of fractures of the bones. The setting of the fractures was generally defective, indicating little if any surgical knowledge of these conditions. On the other hand, wounds of the skull, especially at Pachacamac, were very numerous.

Of trephining no postive example was discovered in the valley of Chicama and but one at Pachacamac; but there are several skulls in which it is impossible to say whether they present a partially healed wound from a club or a scar from trephining. It may also be that some specimens of trephining have been taken by the peons and brought to the local collectors; but numerous cemeteries were examined to which this could not apply.

From an archeological point of view the exploration brought out with special force the fact that the scientific value of such Peruvian collections of pottery and other antiquities as have been or are being made by the untrained local collectors, is very small. It was seen throughout that the peons gather indiscriminately what is salable and dispose of it now to this buyer and now to another according to the amount offered. These buyers make the collections for profit and though some of them are of fair and even professional education, they possess and care for no real archeological knowledge, and generally do not attempt in the least any type or even locality identification. In consequence, every large collection that has been sold from Peru by such collectors, represents a heterogeneous mass of articles proceeding from different epochs and even different peoples, and what it can amount to scientifically, under such circumstances, can easily be imagined. If ancient Peru is to be known properly, it will be necessary, as in Egypt, to re-dig the plundered cemeteries, establish the relations between the articles buried and the type and period of the people, and to collect and note every object the graves offer, not merely such as have commercial value. Perhaps on the basis of such work it will then become possible to properly classify the existing Peruvian archeological collections in our institutions.

A JAR, 16 CM. HIGH BY 23.5 CM. BROAD, FROM ONE OF THE LESS ANCIENT GRAVES IN THE VALLEY OF CHICAMA, PERU. ONE OF THESE VESSELS OF SAME TYPE, RECOVERED FROM TWO NEIGHBORING GRAVES OF MEN. THE SKULLS OF BOTH WERE DOLICHOCEPHALIC AND FREE FROM ANY DEFORMATION.

STANFORD LIBRARIES

One word more as to the skeletal material collected. The quantity of this material, which exceeds that from any other limited region in America or elsewhere, presents a reference series of the highest value, which will be freely open to scientific investigators who may wish to consult it.

To the above brief report, the writer has added a bibliography, which will enable the reader to appreciate what has hitherto been done in Peruvian anthropology. Many of the specimens mentioned separately, however, have been reported upon by two or even more writers, so that the total number of described crania is much smaller than would appear. Moreover, a great majority of the enumerated skulls were deformed; and the measurements or observations in many cases are very inadequate. Contributions of a more general nature, or such as apply to special features (trephining, etc.) are not included.[1]

The four plates of illustrations accompanying this paper show a number of the more interesting specimens from the small archeological collection made by the writer in the valley of Chicama while gathering the skeletal remains.

BIBLIOGRAPHY OF THE PHYSICAL ANTHROPOLOGY OF PERU

BLAKE, JOHN H. Notes on a Collection from the Ancient Cemetery at the Bay of Chacota, Peru. Eleventh Annual Report of the Peabody Museum of Archeology and Ethnology, Cambridge, 1878, pp. 277-304.

Notes and some measurements on 7 skulls from Chacota (near Arica).

BLAKE, CHARLES CARTER. On the Cranial Characters of the Peruvian Races of Man. Trans. Ethnol. Soc., N. S., Vol. 2, London, 1863, pp. 216-231.

General classification.

BLAKE, C. C. On a Skull from the Chincha Islands. Journ. Anthr. Soc., Vol. 7, London, 1869, pp. lxvii-lxx.

Notes, a few measurements and a discussion without importance.

BUSK, GEORGE. Remarks on a collection of 150 ancient Peruvian skulls, presented to the Anthropological Institute by T. J. Hutchinson.

In Hutchinson (Thos. J.): Two Years in Peru, Vol. 2, London, 1873, pp. 309-318.

Brief report on 43 skulls from Ancon, 60 from Pasmayo and 46 from Cañete valley.

[1] Historical, ethnographical and other works on Peru are given, to a large extent, but with numerous errors, in Dorsey (Geo. A.): "A Bibliography of the Anthropology of Peru," Field Columbian Museum Publication No. 23, Chicago, 1898.

DAVIS, J. BARNARD. On Ancient Peruvian Skulls (with pl. 9). Journ. Anthr. Institute Great Britain and Ireland, Vol. 3, London, 1874, pp. 94-100.

Also in Hutchinson (Thos. J.): Two Years in Peru, Vol. 2, 8°, London, 1873, pp. 318-320.

No new observations on undeformed skulls. Contests, on the basis of a small series of deformed specimens, D. Wilson's opinion that there are in Peru, besides the naturally brachycephalic, also naturally dolichocephalic crania.

DAVIS, JOSEPH BARNARD. Thesaurus Craniorum. 8°, London, 1867, pp. 240 *et seq.* Supplement, 8°, London, 1875, pp. 51 *et seq.*

Principal measurements and some observations on 7 Aymara, 9 Quichua (without locality), 6 Arica, 3 Tucua, 8 Cerro di Oro, 4 Cañete valley, 10 near Callas, 3 Pachacamac, 2 Chincha islands, and several other skulls from different localities.

DORSEY, GEO. A. Crania from the Necropolis of Ancon, Peru. Proc. Amer. Assoc. Adv. Sci., Vol. 43, 1894, pp. 1-12.

Notes and measurements on 123 skulls from Ancon.

FLOWER, W. H. Catalogue of the Specimens . . . in the Museum of the Roy. Coll. of Surgeons of England. 2d ed., Vol. 1, 8°, London, 1907, pp. 281 *et seq.*

Measurements and notes on 36 skulls from Pasmayo, 7 from Santos, 27 from Ancon, 30 from Cerro del Oro, 5 from Huacho, and a number from other localities.

FORBES, DAVID. On the Aymara Indians of Bolivia and Peru. Journ. Ethnolog. Soc., London, Vol. 2, 1869-1870, pp. 193-305.

Observations and measurements on living Aymara.

GOSSE, L. A. Dissertation sur les races qui composaient l'ancienne population du Perou. Mém. Soc. d'Anthr., Vol. 1, Paris, 1861, pp. 149-176.

Criticism of Tschudi's statements.

MEIGS, J. AITKEN. Catalogue of Human Crania in the Collection of the Academy of Natural Sciences of Philadelphia, 8°, Philadelphia, 1857.

Notes and a few measurements on 14 skulls from Arica, 77 from Pachacamac, 44 from Pisco, 5 from Santa, 5 from Lima and 7 miscellaneous. Largely the same as in Morton's Crania Americana.

MEIGS, J. A. Observations upon the Cranial Forms of the American Aborigines. Proc. Acad. Natur. Sci., Phila., 1866; separate 8°, pp. 1-39.

Brief anthropometric notes on 104 crania from Pachacamac, 63 from Pisco, 31 from near Arica, 14 from near Lima, 9 from Paraccas bay, 8 from Santa, 2 from Payta, and 1 each from Gyamay and Chimu.

MORTON, SAMUEL GEORGE. Crania Americana. Philadelphia, fol., 1839, pp. 96-133.

Observations and measurements on 23 skulls from Pachacamac, 3 from near Arica, and 1 each from Gran Chimu and Santa.

DE QUATREFAGES, A., and E. T. HAMY. Crania Ethnica. 4°, Paris, 1873-1882, pp. 467, 474-475.

Brief notes and principal measurements on about 60 undeformed crania from Bolivia and Peru (Ancon, Chancay, Pachacamac, etc.).

1. CLAY FIGURE FROM AN OLD NATIVE GRAVE IN THE VALLEY OF CHICAMA, PERU (MAXIMUM BREADTH OF HEAD, 6.8 CM.).
2. CAST OF A FIGURE FROM A MOLD FOUND IN THE VALLEY OF CHICAMA, PERU (MAXIMUM BREADTH OF PART ABOVE THE HANDS, 5 CM.).

SMITHSONIAN LIBRARIES

Stanford Libraries

RANKE, JOHANNES. Ueber Altperuanische Schädel von Ancon und Pachacamac. Abhandlungen der mathematisch-physikalischen Classe d. München. Academie der Wissenschaften, Bd. 20, 1899-1900, pp. 631-750, and plates.

Report on 17 skulls from Pachacamac and 12 from Ancon.

RETZIUS, A. Ueber die Schädelform der Peruaner. Ethnologische Schriften. Fol., Leipzig, 1864, pp. 94-98.

Remarks on 8 skulls, 5 of which from Pisco, with measurements of two.

RICCARDI, DR. PAOLO. Memoria del crani e Oggetti de gli antichi Peruviani appartenenti al Museo Civico di Modena e al Museo di Anatomia Umana de la R. Universita di Modena. Archiv Anthr. & Ethnologia, Firenze, Vol. 16, 1886, pp. 305-405.

Measurements and description of 17 skulls from Ancon, 1 from Arica; some data on additional 12, partly from Ancon, partly?

RIVERO, M. E., and J. J. v. TSCHUDI. Antiguëdades Peruanas. 4°. Vienna, 1851; Transl., 8°, New York, 1855.

Includes dissertation on types of Peruvian crania. Repeated in several of Tschudi's works.

RÜDINGER, N. Ueber künstlich deformirte Schädel und Gehirne von Südsee-Insulanern, Abh. bayer. Akad. Wiss., Vol. 11, Bd. 16, München, 1887.

Includes report on two deformed skulls from Ancon, Peru.

SCHREIBER, W. Beitrag zur Kraniologie der altperuanischen Schädel; Zeitschr. Morphol. Anthr., Vol. 12, Stuttgart, 1909, pp. 243-260.

Observations and some measurements on 102 Bolivian and Peruvian skulls (Ancon 60, Puno 7, Arequipa 6, Arica 4, Cajamarquilla 2, Cochabamba 2, etc.).

SERGI, G., and L. MOSCHEN. Crani peruviani antichi del Museo antropologico nella Università di Roma. 1887. 8°. Archiv Anthrop. & Ethnol., Firenze, Vol. 17, 1887, pp. 5-26.

Notes and measurements on 21 skulls, 12 from the vicinity of Lima, 3 from Ancon and 6 from unknown localities on the west.

STOLYHWO, C. Crânes Péruviens. Bull. Acad. Sciences de Cracovie, Fevrier 1906, pp. 109-138.

Detailed measurements and notes on 92 skulls, nearly all deformed, localities not given.

TSCHUDI, J. J. v. See Rivero and Tschudi.

VIRCHOW, R. Crania Ethnica Americana, fol., Berlin, 1892.

Measurements and description of 4 skulls, 2 from Paucartambo, 1 from Ancon and 1 from Iquique. Deformation. Exostoses in auditory canal.

VIRCHOW, R. Schädel (Peruanische). In Reiss (W.) and Stübel's (A.): "Das Todtenfeld von Ancon in Peru," fol., Vol. 3, Berlin, 1887, Taf. 108-116.

Illustration, notes on and measurements of 3 skulls from Ancon.

VRAM, UGO G. Contributo all'antropologia antica del Peru. Atti della Societa Romana di Antropologia, Vol. 7, Roma, 1900-1901, pp. 44-93.

Measurements and observations on 24 crania, 3 from Tacna, 3 from Caudivilla, 1 from Iquique and 17 derivation not stated. Also on some other parts of the skeleton.

VRAM, U. G. Secondo contributo all'antropologia del Peru antico. (Craniologia: varieta craniche con speciale riguardo all'accrescimento del teschio). Atti Soc. Romana di Antrop., 7, 1901, pp. 67-69. Nineteen skulls, 15 from Ancon, 4 from Lima.

WILSON, D. Physical Ethnology: The American Cranial Type. Seventeenth Ann. Rep. Smithsonian Inst. for 1862, Washington, 1863, pp. 249 *et seq.*

Observations and some measurements on 39 Bolivian and Peruvian skulls, 14 from near Arica, 13 from Pachacamac, 4 from Titicaca, 2 from near Lima, 1 from Santa and 5 locality unknown.

WYMAN, J. Observations on Crania and Other Parts of the Skeleton. Fourth Ann. Rep. Peabody Museum, Boston, 1871, pp. 10-24.

Gives measurements and some observations on 6 skulls of Aymaras from Bolivia; and on 14 skulls from Casma, 16 from Amacavilca, 7 from Gran Chimu, 4 from Trujillo, 4 from Pachacamac, 5 from Cajamarquilla, Peru; all, or nearly all, deformed.

WYMAN, J. Crania. Seventh Ann. Rep. Peabody Museum, Cambridge, 1874, pp. 8-15.

Observations and some measurements on 330 skulls from Ancon.

1

2

1. PIECE OF A BLACK VASE FROM A GRAVE IN THE VALLEY OF CHICAMA, PERU (GREATEST BREADTH, 10.3 CM.). 2. TIGER'S HEAD IN CLAY, PAINTED WHITE AND RED, FROM AN OLD GRAVE IN THE VALLEY OF CHICAMA, PERU (GREATEST BREADTH, 7.4 CM.).

STANFORD LIBRARIES

SMITHSONIAN MISCELLANEOUS COLLECTIONS

VOLUME 56, NUMBER 17

NEW SPECIES OF RODENTS AND CARNIVORES FROM EQUATORIAL AFRICA

BY

EDMUND HELLER

Naturalist, Smithsonian African Expedition

(PUBLICATION 2006)

CITY OF WASHINGTON

PUBLISHED BY THE SMITHSONIAN INSTITUTION

February 28, 1911

NEW SPECIES OF RODENTS AND CARNIVORES FROM EQUATORIAL AFRICA

By EDMUND HELLER

Naturalist, Smithsonian African Expedition

Further study of the mammals collected by the Smithsonian African Expedition has made necessary the description of twenty-one additional new forms which are dealt with in the present paper. The bulk of these new forms are from Rhino Camp, in the Lado Enclave. The specimens in the collection are the first which have been obtained in this unknown region. The Lado Enclave comprises the Nile watershed lying west of the Upper Nile (Bahr-el-Jebel). The precise geographical position of Rhino Camp is latitude 2° 55′ north, on the west bank of the Nile some fifteen miles north of the station of Wadelai.

This paper is the thirteenth dealing with the results of the expedition. Incidentally a new *Lophuromys* from West Africa is here described.

HELIOSCIURUS MULTICOLOR MADOGÆ, new subspecies

Nimule Tree Squirrel

Type from Uma (50 miles north of Nimule), Uganda; adult male, number 164828, U. S. Nat. Mus.; collected by Kermit Roosevelt, February 11, 1910; Loring number, 8991.

Characters.—Size of *lateris*, but coloration distinctively buffy, the feet and under parts pure buffy yellow.

Coloration.—General coloration of upper parts mixed buffy, grayish, and black; individual hairs annulated, basally black, then ochraceous, followed by a broad band of black and then by a narrower subterminal band of grayish buff and terminated by a black tip. Eyes with a broad whitish eye-ring, cheeks and feet buffy. Tail annulated with buffy and black bands of equal width. Under parts and inside of limbs buffy; under side of tail basally, and anal region, tawny rufous in marked contrast to rest of under parts.

Measurements.—Head and body, 202 mm.; tail, 204; hind foot, 44. Skull: condylo-incisive length, 41.5; basilar length, 35; zygomatic breadth, 27.5; interorbital width, 13.5; length of nasals, 14; upper toothrow, 9; condylo-incisive length of mandible, 30.5.

This form of the widespread *multicolor* group is decidedly more buffy than its Lado ally, *lateris*, approaching more the color of *elegans* of Mr. Elgon. It is, however, distinctly smaller than this form and somewhat yellower.

The type is the only specimen in the collection. This was secured by Kermit Roosevelt in a clump of bamboo near the village of Uma.

PARAXERUS KAHARI, new species

MERU FOREST SQUIRREL

Type from Meru Boma, northeast of Mt. Kenia, British East Africa; adult female, number 164203, U. S. Nat. Mus.; collected by Edmund Heller, September 24, 1909; original number, 1174.

Characters.—Like *ganana*, but tail without rusty median stripe; skull larger and proportionately broader.

Coloration.—General dorsal coloration buffy olive, darkest medially, becoming lighter and more buffy on the sides; individual hairs annulated by a narrow subterminal band of buff; overlaid by longer wholly black hairs; dark area of back bordered by an obsolete lighter stripe. Eye with a broad buffy ring. Cheeks and lower sides olive buff. Feet above ochraceous. Ears like dorsum. Tail mixed blackish and buffy, without marked darker cross-bands, the border light buffy; below more yellowish buffy. Under parts cream buff, the hair on median line buffy to the roots.

Measurements.—Head and body, 175 mm.; tail, 172; hind foot, 38. Skull: condylo-incisive length, 36.5; basilar length, 31.5; zygomatic breadth, 24.5; interorbital width, 11.5; length of upper toothrow, 7.3; condylo-incisive length of mandible, 27.5.

This race is closely allied to *ganana* of Jubaland. Specimens from the northern Guaso Nyiro River are exactly like the type in body coloration, but are somewhat smaller skulled. In coloration of upper parts this race is similar to *ochraceus* from Mombasa, but the coast species is at once distinguishable by its bright ochraceous under parts.

Among the Wameru tribe this squirrel is known as *kahari*.

GRAPHIURUS PERSONATUS, new species

MASKED DORMOUSE

Type from Rhino Camp, Lado Enclave; adult female, number 164827, U. S. Nat. Mus.; collected by J. Alden Loring, January 11, 1910; original number, 8644.

Characters.—Dorsal coloration buffy, as in *lorraineus*, but size much less.

Coloration.—General dorsal colors buffy, overlaid by sepia, the buffy purer on sides and head and sharply defined against the gray of the under parts. Eye surrounded by a narrow black ring, which is continuous with a black streak to the tip of the snout. Cheeks creamy buff to level of eyes, where some fulvous separates it from the darker color of the upper parts; this light creamy color ascends behind ears and appears above them as a whitish tuft above each ear. Under parts grayish, washed with pale primrose yellow. Fore feet whitish, hind limbs broccoli brown like the tail; the toes and sides of the feet white. Tail above broccoli brown, the hairs lightening at tip and forming a light border; under surface lighter grayish or brown, but darkening toward tip, where it is the color of the upper surface.

Measurements.—Head and body, 82 mm.; tail, 63; hind foot, 14; ear, 10. Skull: condylo-nasal length, 23; zygomatic breadth, 13.5; length of nasals, 8.5; interorbital width, 4.3; length of upper tooth-row, 3.

Skull smaller than *lorraineus*, with shorter snout and smaller teeth. This species resembles *lorraineus* most closely in color and size. From *smithii*, which is about the same size, it differs widely in color, being buffy instead of grayish, with a distinct black eye-ring.

There is but a single specimen in the collection.

DENDROMUS SPECTABILIS, new species

NILE BLACK-FRONTED TREE MOUSE

Type from Rhino Camp, Lado Enclave; adult female, number 164815, U. S. Nat. Mus.; collected by J. Alden Loring, January 18, 1910; original number, 8783.

Characters.—Like *nigrifrons*, but lighter, the under parts pearl gray; feet whitish and the upper parts cinnamon fawn.

Coloration.—Color of upper parts cinnamon fawn, changing on lower sides and head to tawny buff, but not sharply defined against the pearl gray of the under parts; a wide black median dorsal line from shoulders to root of tail, widest anteriorly and narrowing gradually posteriorly; a median black spot on forehead midway between eye and ear. Snout lighter than rest of head, pure buffy yellow; base of whiskers and area between eye and tip of snout

blackish. A few white hairs at anterior base of ears and a larger white patch immediately below ear. Ears dark seal brown with a few silvery hairs on inside. Feet whitish. Lower parts pearl gray, the hair basally slate gray except on chin, throat, and under lip, which are white; median line of belly buffy. Tail dusky brown all around, essentially naked.

Measurements.—Head and body, 68 mm.; tail, 78; hind foot, 17.5. Skull: greatest length, 21; condylo-incisive length, 18.5; zygomatic breadth, 11.8; nasals, 7.5; diastema, 5; length of upper molar series, 3.1; condylo-incisive length of mandible, 12.

This species is allied to *nigrifrons*, but is readily distinguishable by its lack of buffy under parts and whitish feet. The series of eight topotypes shows very little variation in the color of the under parts.

DENDROMUS LINEATUS, new species

LADO TREE MOUSE

Type from Rhino Camp, Lado Enclave; adult male, number 164816, U. S. Nat. Mus.; collected by J. Alden Loring, February 1, 1910; original number, 8921.

Characters.—Size of *jamesoni* and coloration of *ochropus*, with short ears and small skull and feet.

Coloration.—Upper parts tawny ochraceous, lighter on the sides, ochraceous where the color is well defined against the white of the under parts; head lighter than body, ears darker umber-brown; a wide black median stripe extending from the shoulders to the base of the tail. Fore feet and under parts pure white, the hair white to the roots. Tail bicolor, dusky brown above, white below.

Measurements.—Head and body, 65 mm.; tail, 87; hind foot, 16.5. Skull: greatest length, 20; basilar length, 14.5; condylo-incisive length, 17.2; zygomatic breadth, 10; nasals, 7.2; diastema, 5; length of upper toothrow, 3.5; condylo-incisive length of mandible, 11.5.

Twelve topotypes are in the collection. This series shows great variation in the distinctness of the black median dorsal stripe. In seven of these it is well defined, but in the remaining five there are all degrees of obsoleteness down to specimens which show only a very faint trace.

Dendromus jamesoni of the Transvaal seems to be a close ally of this species, the chief differences separating the two forms being the lesser zygomatic width of the skull and the smaller ear of the

Nile species. This new form approaches *ochropus* of British East Africa closer than any other equatorial species. From this species it is readily separable by the white under parts and the bicolored tail, and also by slightly smaller skull and feet.

Two other specimens, both with stripe obsolete, are in the collection from Hoima and Gondokoro, Uganda.

MUS MUSCULOIDES EMESI, new subspecies

UGANDA PYGMY MOUSE

Type from Kabula Muliro, Uganda; adult male, number 164819, U. S. Nat. Mus.; collected by J. Alden Loring, December 27, 1909; original number, 8497.

Characters.—Dorsal coloration similar to *murillus;* hair of under parts white to the roots; body size less, with proportionately smaller skull.

Coloration.—Median dorsal area blackish, sparingly flecked with tawny; sides lighter and more tawny, the lower sides well defined against the white of the under parts by a narrow band of fulvous; dorsal pelage composed of black hairs annulated with tawny and of scattered wholly black hairs. Limbs like sides, ears and dorsal surface of tail blackish and clothed by minute hairs. Feet and under parts white, the hair white to the roots. Lower side of tail whitish.

Measurements.—Head and body, 71 mm.; tail, 51; foot, 13.5. Skull: greatest length, 20.1; condylo-incisive length, 18.5; nasal, 7.9; zygomatic breadth, 10.5; palatal foramina, 4.4; upper molar series, 3.5.

Skull similar to *murillus* and to the members of the *musculoides* group generally, having the masseter knob and anterior cusp of m^1 little pronounced. This is a small white-bellied Nile race of the widespread *musculoides* group.

The series of nine topotypes shows considerable variation in dorsal coloration, ranging from the dark color of the type to a rufous phase. A specimen taken at Hoima, Uganda, is also referable to this new form.

MUS WAMÆ, new species

LONG-SNOUTED PYGMY MOUSE

Type from Kapiti Plains, British East Africa; adult female, number 161777, U. S. Nat. Mus.; collected by J. Alden Loring, May 6, 1909; original number, 6061.

Characters.—Long snouted like *sorellus*, but snout longer, the nasal bones measuring 8.5 mm. in length; upper parts much lighter, ochraceous-buff.

Coloration.—Median dorsal region from eyes to base of tail ochraceous-buff, heavily lined with black; snout and sides of head and body from level of eyes purer ochraceous-buff, changing to fulvous on lower sides where this color meets the white of the under parts. Ears hair brown, an ill-defined white spot at their base. Tail nearly naked; light brownish above, whitish below. Under parts, feet, and snout from level of nose, white; the hair white to the roots.

Measurements.—Head and body, 68 mm.; tail, 40; foot, 15. Skull: occipito-incisive (greatest) length, 20.5; condylo-incisive length, 20; length of nasals, 8.5; width of interorbital constriction, 3.2; length of palatal foramina, 5.4; width of brain case, 9; length of upper molar series, 3.6.

This species is closely allied to *sorellus*, with which it agrees in the peculiar elongate snout and straight projecting incisors, and also in general proportions of body. *Sorellus* is, however, only distantly related to *gratus*, but shows close relationship to *tenellus* in the formation of the short, narrowed mesopterygoid region, straight incisors and short tail. The group to which this species belongs represents the extreme divergence of the African Leggadas from the *Mus musculus* group in skull characters. This difference from the type species of *Mus* is most marked in the straight, projecting incisors, the elongate snout, the abbreviated, narrow, mesopterygoid fossa, and the minute coronoid process of the mandible. In the two latter characters these long-snouted African *Mus* approach somewhat the skull condition exhibited by *Acomys*.

This is rather a rare species, being represented by only one skin and one alcoholic specimen in the collection, which contains some hundred specimens of Leggadas from British East Africa.

MUS TENELLUS ACHOLI, new subspecies

LONG-SNOUTED PYGMY MOUSE

Type from Rhino Camp, Lado Enclave; adult male, number 164817, U. S. Nat. Mus.; collected by J. Alden Loring, January 13, 1910; original number, 8671.

Characters.—Coloration of *tenellus*, but size much larger, with large skull and proportionately short tail.

Coloration.—Median dorsal area mixed blackish and fulvous, the

snout and posterior rump more fulvous; sides pure fulvous, fairly well defined against the dark dorsal area and the white of the under parts; limbs fulvous like the sides. Ears blackish, covered sparingly by minute grayish hairs. A conspicuous white subaural patch. Feet and under parts white, the hair white to the base. Tail hair brown above, whitish below, closely covered by short stiff hairs which hide the annuli.

Measurements.—Head and body, 68 mm.; tail, 36; foot, 13. Skull: greatest length, 20.5; condylo-incisive length, 19; zygomatic breadth, 10; palatal length, 11; nasals, 8; length of upper molar series, 3.3; palatine foramina, 5.

This is a larger race of the *tenellus* group of the Lower Sudan, of which it is the extreme in size. From *suahelica* of the Kilimanjaro region this species differs widely in its much larger size and lighter coloration. The *tenellus* group is well defined by its long snout, projecting incisors, and short hairy tail. Three other specimens are in the collection from the type locality.

MUS GRATUS SUNGARÆ, new subspecies

KENIA PYGMY MOUSE

Type from West Kenia Forest Station, altitude 7,500 feet; old male, number 163487, U. S. Nat. Mus.; collected by J. Alden Loring, September 20, 1909; original number, 7425.

Characters.—Like *gratus*, but larger and lighter colored, with the central dark area better defined.

Coloration.—Median dorsal area from snout to base of tail mixed blackish and tawny in about equal parts; sides lighter, purer tawny, changing somewhat abruptly from the dark dorsal region; bounded on lower sides where the sides meet the white of the under parts by a fulvous line. Ears hair brown. Tail dark brown above, light brown below. Under parts and feet white, the hair white to the roots.

Measurements.—Head and body, 70 mm.; tail, 60; hind foot, 14.5. Skull: occipito-nasal (greatest) length, 19.5; condylo-incisive length, 18.2; basilar length, 15.5; zygomatic breadth, 10; length of nasals, 7.2; length of palatal foramina, 4.9; length of upper tooth-row, 3.5.

The material of this form in the collection is quite extensive. From the type locality there are six specimens, ten from Nyeri, seven from Waubugus, and eight from Naivasha. There is con-

siderable variation due to age, the young usually having the under parts quite buffy with the hair basally plumbeous, the pure white under parts being acquired only in old adults.

MUS BELLUS GONDOKORÆ, new subspecies

GONDOKORO PYGMY MOUSE

Type from Gondokoro, Uganda; adult male, number 164820, U. S. Nat. Mus.; collected by J. Alden Loring, February 25, 1910; original number, 9089.

Characters.—Smaller and lighter colored than *bellus*, with the subaural white spot well defined.

Coloration.—Median dorsal area from eyes to posterior rump hair brown, much lighter than the fulvous sides against which it is not well defined; snout, area about eye, limbs, and sides of body bright fulvous, sharply contrasted with the white of the under parts. Ears hair brown like back. Under parts, tip of snout, and lips and feet, white; the hair white to the roots. Tail brown above, lighter and whiter below.

Measurements.—Head and body, 60 mm.; tail, 43; hind foot, 13. Skull: greatest length, 17.6; condylo-incisive length, 16; zygomatic breadth, 9.4; nasal, 6.3; length of upper toothrow, 3.

The type is the only specimen in the collection.

MUS BELLUS ENCLAVÆ new subspecies

ENCLAVE PYGMY MOUSE

Type from Rhino Camp, Lado Enclave; adult male, number 164818, U. S. Nat. Mus.; collected by J. Alden Loring, January 10, 1910; original number, 8613.

Characters.—Size of *bellus*, but dorsal coloration much darker, the sides nearly as dark as the median region.

Coloration.—Upper parts blackish, the median region very sparingly flecked with tawny; sides more tawny, about equally mixed broccoli brown and tawny; snout dorsally blackish to tip, sides of head and snout tawny ochraceous, enclosing the eye on lower and post[illegible] or side only, the buffy eye-ring being broken above by the blackish suffusion of the head. Ears hair brown, with an indistinct white patch at their base. Tail dark brown above, lighter brownish below. Under parts from level of nostrils and feet white, the hair white to the base.

Measurements.—Head and body, 64 mm.; tail, 46; hind foot, 13. Skull: occipito-nasal (greatest) length, 18; condylo-incisive length, 16.5; length of nasals, 6.2; zygomatic breadth, 9.2; palatal foramina, 4.3; length of upper toothrow, 3.1.

This is a dark form of the widespread *bellus*. A series of thirteen from Rhino Camp show very little variation in the dark upper parts and are readily distinguishable from the light sided *bellus*, with its sharply defined dark dorsal area.

ARVICANTHIS PULCHELLUS MICROPUS, new subspecies

LADO STRIPED GRASS RAT

Type from Rhino Camp, Lado Enclave; adult female, number 164825, U. S. Nat. Mus.; collected by J. Alden Loring, January 24, 1910; original number, 8861.

Characters.—Closely allied to *massaicus*, but feet smaller and skull narrower.

Coloration.—General dorsal coloration bistre brown; the back marked by ten parallel lines of ochraceous spots, the central pair enclosing a median black dorsal line; sides lighter and more grayish, the spots light buffy. Feet and ears ochraceous. Tail blackish above, buffy on sides and below. Under parts cream buff, the hair uniform to the roots.

Measurements.—Head and body, 114 mm.; tail, 125; hind foot, 23. Skull: condylo-incisive length, 25; zygomatic breadth, 23.5; nasals, 11 x 3; diastema, 7; length of upper toothrow, 5.2; length of bullæ, 5; condylo-incisive length of mandible, 18.

There are eleven topotypes in the collection. In color these range from the grayish color of *massaicus* to a buffy tint similar to *ardeus*. A series from Uganda, taken along the route from Kampala to Butiaba, agree in the small size of their feet and in color with the types series. One specimen from Gondokoro has the spots so coalesced as to form lines as in *barbarus*, from which it is not distinguished except in the flatter skull and darker olivaceous body color.

ARVICANTHIS JEBELÆ, new species

WHITE-BELLIED GRASS RAT

Type from Rhino Camp, Lado Enclave; number 164826, U. S. Nat. Mus.; collected by J. Alden Loring, January 16, 1910; original number, 8762.

Characters.—Tail long, length equaling head and body or greater; nasal bones slightly concave along lateral edges; upper parts tawny ochraceous, lower parts white.

Coloration.—Upper parts tawny ochraceous, sparingly lined by black; purer ochraceous on sides, the color extending low down on sides of belly, but not sharply defined against the white under parts; pelage made up of narrowly seal brown tipped hairs with a broad band of ochraceous followed by slate to the base, the subterminal ochraceous band giving the pelage its color character; interspersed with these annulated hairs are longer black ones, which give the median dorsal area a lined effect. Eyes with an ill-defined buffy ring. Ears chiefly ochraceous, with a few black hairs about the base and on the inner side. Feet ochraceous. Tail with a broad dorsal band of black, the sides buffy and the lower surface whitish. Under parts white, the hair white almost to the roots, the base ashy gray; on chin, lips, throat, and thighs the hair is white to the roots.

Measurements.—Head and body, 140 mm.; tail, 150; hind foot, 29. Skull: condylo-incisive length, 31.5; greatest length, 35.5; zygomatic breadth, 17; interorbital constriction, 5; nasals, 12.5 x 4; length of upper row, 6.5; diastema, 8.2; length of palatine foramina, 5.5; length of bullæ, 5.6; condylo-incisive length of mandible, 22.

This species occurs at its type locality with *rubescens*, both being forms of the *abyssinicus* group. Both forms occur about Gondokoro also. The color differences from the dark-bellied, shorter-tailed *rubescens* are marked, but the skull differences consist of only average characters, such as the slight concavity to the edges of the nasal bones and the lack of beading to the anterior part of the interorbital region.

The type locality is represented by a series of twenty-four skins in which are specimens of all ages, but the variation in color is very little. The relationship between length of head and body and the length of the tail in this series shows the following proportion: tail longer than head and body, 8 specimens; tail equal to head and body, 6 specimens; tail slightly shorter than head and body, 10 specimens.

LOPHUROMYS PYRRHUS, new species

LADO HARSH-FURRED MOUSE

Type from Rhino Camp, Lado Enclave; adult male, number 164823, U. S. Nat. Mus.; collected by J. Alden Loring, January 24, 1910; original number, 8853.

Characters.—Size large, skull long-snouted; under parts bright orange-rufous.

Coloration.—Upper parts uniform seal brown, becoming lighter only on lower sides where the coloration merges gradually from burnt umber to the cinnamon rufous of the belly. Feet lighter than back, vandyke brown. Tail quite blackish above and on the sides, the median under surface becoming lighter. Under fur of upper parts chestnut brown. Under parts from chin to base of tail bright cinnamon rufous, the color uniform to the roots of the hair.

Measurements.—Head and body, 136 mm.; tail, 72; hind foot, 22.5. Skull: condylo-incisive length, 31; basilar length, 27; zygomatic breadth, 15.5; interorbital width, 6.7; length of nasals, 14; length of upper toothrow, 5; condylo-incisive length of mandible, 22.5.

Compared to *ansorgei* of the Kavirondo country of British East Africa, this form has the under parts much brighter red, the intensity of the red persisting through old age. *Sikapusi*, which has the same bright under parts, is a smaller race with a decidedly broader skull, with shorter, more convex nasal bones.

LOPHUROMYS NUDICAUDUS, new species

Type from Efulen, Bula country, Kamerun; adult male, number 125436, U. S. Nat. Mus.; collected by G. L. Bates, August 4, 1903; original number, 26.

Characters.—Tail essentially naked, the annulations conspicuous; hair very harsh; skull with small flattened bullæ and shortened brain case, the parietal bones short.

Coloration.—Upper parts uniform seal brown, the hair uniform in color to the roots on median line, but lightening on sides. Feet vandyke brown. Under parts chiefly cinnamon rufous, the chest orange rufous. Tail quite naked, with distinct annulations, uniform deep seal brown in color.

Measurements.—Total length, 166 mm.; tail (skin), 60; foot, 18.5. Skull: condylo-incisive length, 25; basilar length, 21; zygomatic width, 13.5 (approximate); interorbital width, 6.5; length of nasals, 11.6; length of upper toothrow, 4.4; condylo-incisive length of mandible, 17.3.

This is a small species of *Lophuromys* and differs from the other described species in its very much harsher fur and essentially naked tail.

URANOMYS UGANDÆ, new species

UGANDA BIG-TOOTHED MOUSE

Type from Kikonda, Uganda; adult male, number 164822, U. S. Nat. Mus.; collected by J. Alden Loring, January 2, 1910; original number, 8570.

Specific characters.—Most closely related to *ruddi* of the Mount Elgon District of British East Africa. Differs decidedly in the shorter and narrower skull and the shorter nasal bones. Size smaller and coloration of under parts without any pinkish wash.

Coloration.—Median portion of head and body above sepia flecked minutely with light brown, changing gradually on sides of head and body to a fulvous flecked with sepia. Under parts light grayish with a buffy wash. Fore and hind limbs with the color of the sides, except the feet, which are white. Tail dusky brownish above, becoming somewhat lighter below.

Measurements.—Head and body, 101 mm.; tail, 75; hind foot, 18; ear, 12. Skull: greatest length, 27; condylo-basal length, 25; zygomatic breadth, 14.5; nasals, 7.5 x 3.5; upper toothrow, 4.5; palatal foramina, 7.5.

The skull of this genus is very close to *Acomys* in structure, the palatal region especially being similar, but externally this species can be scarcely distinguished from *Lophuromys aquilas*, with which it is found associated. The collection contains but a single specimen. The teeth in this individual are quite worn, so that the tubercular structure cannot be made out. Compared with skulls of equal age of *Lophuromys* and *Acomys*, the m_3 is found to lack the minute posterior median cusp which is found in both these genera. The structure of the floor of the skull closely resembles *Acomys*. The depressions marking the termination of the bony palate are, however, much deeper and have prominent margins, the interpterygoid fossa is wider and has parallel sides and blunt bead-shaped pterygoid processes. The mandible resembles more that of *Lophuromys* in the shape of its coronoid process, which is long and slender and very different from the minute projection which is found in *Acomys*. The condylar process is considerably larger than in either *Lophuromys* or *Acomys*. The most marked difference, however, is the prominence given to the incisor capsules. In this genus the capsule forms a prominent shelf-like projection midway between the coronoid and the condylar processes. The incisor condyle of *Acomys* and

Lophuromys is scarcely perceptible on the surface of the posterior portion of the ramus. This genus has the external characters of *Lophuromys* with the palatal skull formation of *Acomys* and distinctive projecting incisors and marked mandibular characters.

ACOMYS HYSTRELLA, new species

GRAY-BACKED SPINY MOUSE

Type from Nimule, Uganda; adult female, number 164821, U. S. Nat. Mus.; collected by J. Alden Loring, February 4, 1910; original number, 8929.

Characters.—Size large; tail three-fourths head and body; dorsal coloration drab gray with fulvous sides; nasal bones short.

Coloration.—Median dorsal region from the snout to the base of the tail drab-gray, this color merging gradually into the fulvous of the sides; fulvous of cheeks, lower sides, and legs sharply defined against the white of the under parts. Spinous hair of sides annulated, the extreme tip seal brown, succeeded by a broad band of fulvous, which is followed by cinereous gray to the base; this annulation is not perceptible in the darker spines of the back, the subterminal band of drab-gray being nearly as dark as the tips. Feet white. A small white spot below the ear. Ears smoky-brown clothed with a mixture of minute brownish and silvery hairs. Tail sharply bicolor; above lighter gray than the back, below whitish. Under parts, including upper lips and feet, white, the hair white to the roots.

Measurements.—Head and body, 111 mm.; tail, 81; hind foot, 16; ear, 15. Skull: greatest length, 28.3; basilar length, 22; zygomatic breadth, 13.2; nasals, 10.5 x 3.5; interorbital constriction, 5; length of palatine foramina, 6.7; length of upper toothrow, 4.5.

From the Somali species, *mullah*, this species differs in its smaller size, more fulvous sides, and shorter tail and nasal bones. The fulvous sides also distinguish it from the grayish *cahirinus* of Egypt, from which it further differs by larger skull and acutely pointed mesopterygoid fossa and smaller bullæ.

DASYMYS ORTHOS, new species

NYANZA SWAMP RAT

Type from Butiaba, Albert Nyanza, Uganda; adult male, number 164824, U. S. Nat. Mus.; collected by J. Alden Loring, January 1, 1910; original number, 8601.

Characters.—Antorbital plate with a straight anterior margin, with scarcely any concavity; bullæ small, coloration brownish; size large.

Coloration.—General dorsal coloration Prout's brown, becoming grayer on the sides and merging gradually into the olive-yellow wash of the gray under parts. Dorsal pelage made up of long black hairs which overlay the nearest shorter ones, which are terminally seal brown, then broadly tawny and basally slate. Limbs light wood brown. Tail showing very little hair, the annulation conspicuous, color broccoli brown.

Measurements.—Head and body 160 mm.; tail, 156; hind foot, 32. Skull: condylo-incisive length, 36.5; zygomatic breadth, 18.5; nasal, 13.5; palatal foramina, 8; length tympanic bullæ, 5.6; length upper toothrow, 7.3; diastema, 11.2; condylo-incisive length of mandible, 26.

This species is a much browner species than *medius*, with larger body size. The skull differs decisively from a large series of *helukus* from British East Africa in its straight-edged antorbital plate, which is scarcely more angulated at its upper edge than in *Epimys alexandrinus*.

There is one other specimen from Butiaba in the collection, and a third from Rhino Camp.

DASYMYS SAVANNUS, new species

KENIA SWAMP RAT

Type from Fort Hall, British East Africa; adult female, number 164471, U. S. Nat. Mus.; collected by J. Alden Loring, October 28, 1909; original number, 8182.

Characters.—Coloration umber-brown, skull with antorbital plate much angulated and produced, giving the antorbital vacuity great depth; size smaller than in *helukus;* tail essentially naked.

Coloration.—Upper parts umber, overlaid medially with black, the individual hairs tawny-ochraceous, with dark brown tips and slaty bases mixed with longer black hairs. Sides lighter, purer ochraceous, becoming more grayish where they meet the olive-gray wash of the lower parts. Feet pale brown. Ears hair brown, clothed with minute grayish hairs. Tail like the ears in color, but quite naked, with the annuli showing conspicuously.

Measurements.—Head and body, 156 mm.; tail, 146; hind foot, 29.5. Skull: condylo-incisive length, 37.5; zygomatic breadth, 19;

nasal, 14; palatal foramina, 8.5; length of bullæ, 6; upper tooth-row, 7.5; diastema, 12.5; condylo-incisive length of mandible, 28.

This species is very much browner than *helukus*, with a less hairy tail in old age, and smaller body size. The angle of the antorbital plate is much more pronounced than in any other specimen in the collection. Interorbital region narrow, the beads on margin much raised and leaving a deep median groove.

A large series of specimens show the age differences in skulls to be great. The interorbital region changes from a flat, weakly beaded condition to a narrow, deeply concave affair with high beads. Bullæ in youth high and rounded, becoming in age flat and broad, antorbital plate less concave in young.

MUNGOS SANGUINEUS ORESTES, new subspecies

KENIA FOREST MUNGOOSE

Type from west slope of Mt. Kenia, altitude 8,500 feet; adult male, number 164152, U. S. Nat. Mus.; collected by J. Alden Loring, October 12, 1909; original number, 7934.

Characters.—Much darker and larger than *sanguineus*, with black predominating on the dorsal surface; skull larger and wider zygomatically.

Coloration.—Median dorsal area from snout to tip of tail blackish; top of head and tip of tail wholly black; back and sides mixed tawny and black, the black predominating; feet like back, only the toes black; sides of face black like the crown. Under parts mixed tawny and dark brown, the tawny predominating.

Measurements.—Head and body, 300 mm.; tail, 282; hind foot, 59. Skull: condylo-basal length, 65; palatal length, 34; zygomatic breadth, 34.5; width of brain case, 26.5; greatest diameter of pm^4, 8.

The series of six topotypes shows considerable variation. The darkest one has the head feet and median line of the back wholly black. The lightest one is somewhat darker than normal specimens of *sanguineus*. This new race is nearest to *proteus* of Mt. Ruwenzori, which lives in very similar environment. It has a longer tail and larger skull, and is much less blackish.

CROSSARCHUS FASCIATUS COLONUS, new subspecies

EAST AFRICAN BANDED MUNGOOSE

Type from the Southern Guaso Nyiro River, Sotik District, British East Africa; adult female, number 162132, U. S. Nat. Mus.; collected by Edmund Heller, June 21, 1909; original number, 6396. J. Alden Loring.

Characters.—Size and proportions as in *macrurus*, but coloration much grayer, the rufous of the shoulders replaced by buffy gray and the feet seal brown.

Coloration.—General dorsal coloration buffy grayish, lined everywhere with blackish; the posterior back and rump marked by eleven dark cross bands which are well defined only on back, being obsolete on the sides. Separating the broad dark cross bands are narrower light bands of buffy, which on median line become ferruginous. Shoulders and limbs uniform in color with the general body color, the feet and the muzzle dorsally from the level of the eyes dark seal brown. Tail like body color, the terminal one-fourth blackish. Under parts with an ochraceous wash, the hairs basally dark brown; throat lighter buffy, the chin and upper lip bright tawny, in marked contrast to rest of under parts.

Measurements.—Head and body, 380 mm.; tail, 260; hind foot, 92. Skull: condylo-basal length, 75.5; basal length, 71; zygomatic breadth, 42.5; palatal length, 39; greatest diameter of pm^4, 7.

This East African veldt race of the banded mungoose is a much grayer and lighter colored animal than *macrurus* of Ruwenzori and Uganda. The rich rufous suffusion of the shoulders and the black feet of the latter are wanting, the body color being quite uniform and the black replaced by brown.

These mungooses are often met with on the grassy plains of the Sotik country, where they live in colonies in burrows on the open veldt. They, however, do not stop long in any locality, but move about in small packs of ten to twenty individuals, which take up a temporary abode in any nest of burrows which they find convenient. From our observations it was apparent that they do not remain more than a day or two in any one set of burrows.

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 56, NUMBER 18

BIBLIOGRAPHY OF THE SCIENTIFIC WRITINGS OF R. E. C. STEAR

BY MISS MARY R. STEARNS

WITH ONE PLATE

WITH BIOGRAPHICAL SKETCH BY

WILLIAM H. DALL

(PUBLICATION 2007)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
1911

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

ROBERT EDWARDS CARTER STEARNS
1827-1909

BIBLIOGRAPHY OF SCIENTIFIC WRITINGS OF R. E. C. STEARNS

By MISS MARY R. STEARNS

(With One Plate)

I. BIOGRAPHICAL SKETCH OF ROBERT EDWARDS CARTER STEARNS[1]

By Dr. W. H. DALL

Dr. Robert Edwards Carter Stearns died at Los Angeles, Cal., July 27, 1909, in his eighty-third year. He was a native of Boston, Mass., a son of Charles Stearns, and was born February 1, 1827. He was educated in the public schools, followed by a course of mercantile training, and from his earliest years evinced a deep love of nature, fostered by his father, with whom similar tastes led to a degree of comradeship in rambles and hunting expeditions which he always remembered with appreciation. The boy had an unusual artistic ability, and, though his early avocations were services in a bank and on a farm, when only twenty-two years of age he painted a panorama of the Hudson River from the mouth of the Mohawk to Fort William, which was sold and exhibited. He turned his attention to mining, explored the coal fields of southern Indiana, and in 1854 was appointed resident agent of several copper mines in northern Michigan, on Lake Superior. In 1858 he went to California, where he became a partner in a large printing establishment of a brother-in-law of his wife, in San Francisco. This firm published the Pacific Methodist, a weekly religious paper, and in the troubled times preceding the civil war the reverend editor of this journal was obliged to visit the east. Stearns was requested to fill his place during his absence. The fate of California hung in the balance, many of the immigrants from the southern states urged independence for that territory when hostilities broke out. Stearns took the responsibility of making his paper an enthusiastic advocate of the Union cause, and to this call and the eloquence of Thomas Starr King, old Californians believed the decision of the people to

[1] Printed also in *Science*, N. S. Vol. 30, No. 765, Aug. 27, 1909, pp. 279-80.

stand by the Union in that struggle was due in no small degree. Through the influence of Justice Field, Stearns was appointed deputy clerk of the supreme court of California in 1862, a post which he resigned in the following year to accept the secretaryship of the State Board of Harbor Commissioners, which he was obliged to resign some years later on account of ill health. Coming to the east, he made one of a party, comprising besides himself the late Dr. William Stimpson and Col. Ezekiel Jewett, for the exploration of the invertebrate fauna of southwestern Florida, during which large collections were made for the Smithsonian Institution. He returned to California, and in 1874 was elected secretary of the University of California, being the business executive of that institution under the presidency of the late Dr. Daniel C. Gilman. He served in this capacity for eight years with great approval, and, when ill health again obliged him to retire from service, the university as expressive of their sense of his services to the cause of education in California, and in recognition of his scientific attainments, conferred upon him the degree of doctor of philosophy. Returning to the east after the death of Mrs. Stearns, he was engaged in researches for the U. S. Fish Commission in 1882, was appointed paleontologist to the U. S. Geological Survey by Major Powell in 1884, and assistant curator of mollusks in the National Museum by Professor Baird. His collection of mollusca was acquired by the museum. Age and infirmity obliged him to return to the more genial climate of California in 1892, where he settled in Los Angeles, continuing, as his strength permitted, his researches into the malacology of the Pacific coast. He married March 28, 1850, Mary Anne Libby, daughter of Oliver Libby, of Boston, and is survived by a daughter.

Dr. Stearns was an earnest student of mollusks from boyhood; his early experience led him to interest himself in horticulture and landscape gardening, and his ability in this line is attested by the beauty of the university grounds at Berkeley, which were developed under his superintendence. His knowledge of the Pacific coast mollusca was profound, and a long list of papers on this topic and on the shells of Florida was the result. He also contributed many papers on various branches of horticulture and gardening to the California periodicals devoted to this subject. He was an enthusiastic supporter of the California Academy of Sciences in its early days, and, after the earthquake of 1868, when disaster threatened the society, he, with Professor J. D. Whitney and a few other friends, stood between it and dissolution. He was a member of

numerous scientific societies at home and abroad, and of the Sons of the American Revolution.

Dr. Stearns was a man of sanguine temperament, with a lively sense of humor and high moral character. His reading was wide, his learning never obtrusive, his interest in art, literature and all good causes, intense. He was a staunch friend and, for a righteous object, ever ready to sacrifice his own material interests. His services to Californian science will keep his memory green.

II. LIST OF SCIENTIFIC PUBLICATIONS BY ROBERT EDWARDS CARTER STEARNS, PH. D.

Fellow American Association for the Advancement of Science; in 1869, chosen Corresponding Member of the Chicago Academy of Science; 1870, Corresponding Member Lyceum of Natural History in the City of New York, now the New York Academy of Science; September 17, 1873, elected Corresponding Member of Die Kaiserlich Königliche Zoölogisch-Botanische Gesellschaft in Wien, Austria; 1877, Corresponding Member of Academy of Natural Science, Davenport, Iowa; 1887, Correspondent of the Academy of Natural Sciences in Philadelphia.

CONCHOLOGY

1. List of Shells collected at Baulines Bay, California, June, 1866.—Proc. California Acad. Nat. Sci., Vol. 3, 1866, pp. 275-276. (C. M. I.[1]) Additions to this list, ibid., p. 291, 1867. (C. M. II.)

2. List of Shells collected at Santa Barbara and San Diego by Mr. J. Hepburn, in February-March, 1866, with Remarks upon some of the species.—Proc. California Acad. Nat. Sci., Vol. 3, 1866, pp. 283-286. (C. M. I.)

3. Remarkable Instance of Vitality in a Snail, *Helix veatchii*.—Proc. California Acad. Nat. Sci., Vol. 3, 1867, pp. 328-329.

4. Shells collected at Santa Barbara by W. Newcomb, M. D., in January, 1867.—Proc. California Acad. Nat. Sci., Vol. 3, 1867, pp. 343-345. (C. M. II.)

5. List of Shells collected at Purissima and Lobitas, California, October, 1866.—Proc. California Acad. Nat. Sci., Vol. 3, 1867, pp. 345-346. (C. M. II.)

6. List of Shells collected at Bodega Bay, California, in June, 1867.—Proc. California Acad. Nat. Sci., Vol. 3, 1867, pp. 382-383. (C. M. III.)

7. Shells collected by the U. S. Coast Survey Expedition to Alaska in the Year 1867.—Proc. California Acad. Nat. Sci., Vol. 3, 1867, pp. 384-385. (C. M. III.)

Also in Report of the Superintendent of the U. S. Coast Survey, for 1867, Appendix No. 18, pp. 291-2; Harford's List, which contains numerous typographical errors, which were not in the original.

[1] This and a number of the following papers were also issued under the title "Conchological Memoranda" by Doctor Stearns and will be referred to as "C. M." in the subsequent annotations. Since the dates of the memoranda were often prior to the publication in serials, it is important that they should be noted, and they are as follows: I, July 16, 1866; II, August 20, 1866; III, December 2, 1867; IV, 1869; V, 1870; VI, May 18, 1871; VII, Aug. 28, 1871; VIII, Oct. 14, 1871; IX, Sept. 4, 1871; X, June 5, 1872; XI, Jan. 17, 1873; XII, April 7, 1873; XIII, Oct. 18, 1875.

38. Observations on Planorbis; are the Shells of Planorbis dextral or sinistral? On certain aspects of Variation in American Planorbes.—Proc. Acad. Nat. Sci., Philadelphia, 1881, pp. 92-110, with 27 figures.

39. Mya arenaria in San Francisco Bay.—Amer. Naturalist, Vol. 15, May, 1881, pp. 362-366.

40. On Helix aspersa in California, and the Geographical distribution of certain West American Land-snails, etc.—Annals New York Acad. Sci., Vol. 2, 1881, pp. 129-139.

41. Verification of the Habitat of Conrad's Mytilus bifurcatus.—Proc. Acad. Nat. Sci., Philadelphia, 1882, pp. 241-242.

42. On the History and Distribution of the Fresh-Water Mussels and the Identity of certain alleged Species.—Proc. California Acad. Sci., November 20, 1882, 21 pp., and figures.

Specially devoted to the Anodons of the Pacific States. Only the separates of this paper were published.

43. On the Shells of the Colorado Desert and the region farther East; Part 1. The Physas of Indio; Part 2. Anodonta californiensis in a new locality.—Amer. Naturalist, Vol. 17, Part 2, October, 1883, pp. 1014-1020, several figures.

Read before the California Acad. of Sci., June 5, 1883.

44. The Edible Clams of the Pacific Coast, and a proposed method of transplanting them to the Atlantic Coast.—Bull. U. S. Fish Com., Vol. 3, 1883, pp. 353-362, with several figures.

Letter to Prof. Spencer F. Baird, U. S. Fish Commissioner, October 14, 1882. *Glycimeris generosa, Saridomus nuttallii* and *Schizothoerus nuttallii*, specially mentioned.

45. Description of a New Hydrobiinoid gasteropod, *Pyrgula Nevadensis*, from the Mountain Lakes of Nevada, with remarks on allied species and the Physiographic features of said region.—Proc. Acad. Nat. Sci., Philadelphia, 1883, pp. 171-176, with figures.

46. Fresh-Water Pearl-mussels.—Mining and Scientific Press, San Francisco, April 7, 1883; Pacific Rural Press, April 14, 1883.

47. The Giant Clams of Puget Sound, *Glycimeris generosa* or *geoduck*.—Forest and Stream, May 28, 1885.

Read at the Washington, D. C., meeting of the American Fisheries Society, April, 1885, and published in the report of said meeting.

48. The Helicidae of the John Day Fauna. Contained in Dr. Charles A. White's paper, "On Marine Eocene, Fresh-Water Miocene, and other Fossil Mollusca of Western North America."—Bull. U. S. Geol. Surv., No. 18, 1885, pp. 14-18, pl. 3.

49. The Teredo, or Ship-worm.—Amer. Naturalist, February, 1886, pp. 132-136, with figures.

From letter to Prof. Spencer F. Baird, Secretary of the Smithsonian Institution.

50. A Mammoth Land Snail.—Nautilus, Vol. 3, No. 3, p. 29, Philadelphia, July, 1889.

51. Notes on *Physa triticea* of Lea; its relations, and comments on the Variation, etc., of *Physae*.—Nautilus, Vol. 3, No. 5, pp. 49-51, Philadelphia, September, 1889.

52. Helix (Stenotrema) hirsuta Say, on the West Coast.—Nautilus, Vol. 3, No. 7, pp. 81-82, Philadelphia, November, 1889.

53. Critiques and Comments.—Nautilus, Vol. 3, No. 6, pp. 64-66, Philadelphia, October, 1889.

Reviews Mr. H. F. Carpenter's article on "The Shell-bearing Mollusca of Rhode Island," in the August, 1889, Nautilus.

54. Notice of and comments on the distribution of Planorbis (Helisoma) bicarinatus Say.—West American Scientist, San Diego, California, September, 1889.

55. Descriptions of new West American Land, Fresh-Water and Marine shells, etc. Scientific Results of Explorations by the U. S. Fish Commission Steamer "Albatross."—Proc. U. S. Nat. Mus., Vol. 13, 1890, pls. 15-17, pp. 205-225.

Describes *Helix (Arionta) coloradoensis, H. (Arionta) magdalenensis, Holospira semisculpta, H. arizonensis, Melania (Goniobasis?) acutifilosa, Cyclothyca corrugata, Mitra (Costellaria?) nodocancellata, Venericardia barbarensis, Lucina aequizonata, Venus (Chione) effeminata, Venericardia ventricosa, Miodon prolongatus,* and *Periploma discus. Cyclothyca,* a new genus, is defined.

56. List of American Land and Fresh-water Shells received from the U. S. Department of Agriculture, etc.—Proc. U. S. Nat. Mus., Vol. 13, 1891, pp. 95-106.

57. List of Shells collected on the West coast of South America, principally between latitudes 7° 30′ S. and 8° 49′ N., by Dr. W. H. Jones, U. S. Navy.—Proc. U. S. Nat. Mus., Vol. 14, 1891, pp. 307-335.

58. Notes on the Sculpture of American Limnaeas, etc.—Nautilus, Vol. 4, No. 11, pp. 121-124, Philadelphia, March, 1891.

59. Edible Mollusks, etc., Here and There.—Nautilus, Vol. 5, No. 1, pp. 2-4, Philadelphia, May, 1891.

60. Edible Shell Notes, for the Nautilus.—Nautilus, Vol. 5, No. 3, pp. 25-26, Philadelphia, July, 1891.

61. Patula strigosa Gould, in Arizona.—Nautilus, Vol. 6, No. 1, pp. 1-2, Philadelphia, May, 1892.

62. Preliminary Descriptions of New Molluscan Forms from West American Regions.—Nautilus, Vol. 6, No. 8, pp. 85-89, Philadelphia, December, 1892.

Uvanilla regina, Chlorostoma gallina var. multifilosa, Bulimulus (Pleuropyrgus) Habeli, Onchidium Lesliei, Littorina (Tectarius) galapagiensis, Nitidella incerta, Littorina (Tectarius) atyphus.

63. Report on the Land and Fresh-water Shells of the Death Valley Expedition.—North Am. Fauna, No. 7, 1893, pp. 269-283. U. S. Dep. Agric., Division of Ornithology and Mammalogy.

Amnicola micrococcus Pilsbry, and *Fluminicola merriami* Pilsbry and Beecher, described and figured.

64. Description of a new species of Nassa (*Nassa brunneostoma*) from the Gulf of California.—Nautilus, Vol. 7, No. 1, pp. 10-11, Philadelphia, May, 1893.

65. Preliminary Report on the Molluscan species collected by the United States Scientific Expedition to West Africa in 1889-1890.—Proc. U. S. Nat. Mus., Vol. 16, 1893, pp. 317-339.

95. An Abnormal Chiton.—Nautilus, Vol. 15, No. 5, pp. 53-54, Philadelphia, September, 1901.

Ischnochiton (Mougerella) conspicuus Cpr., with only six valves. A three-valved *Chiton* also mentioned.

96. Japanese Vivipara in California.—Nautilus, Vol. 15, No. 8, p. 91, Philadelphia, December, 1901.

V. stelmaphora Bgt., in San Jose.

97. The Fossil Fresh-water Shells of the Colorado Desert, their distribution, environment and variation.—Proc. U. S. Nat. Mus., Vol. 24, 1901, pp. 271-299, pls. 19-24, and many figures in the text.

The figures of *Paludestrina protea* represent the more conspicuous aspects of variation, selected from over 40,000 specimens. Of the *Physas* more than 2000 were critically examined and compared.

Some idea of the abundance of these shells on the surface of the desert may be formed from the fact, that about a year after the above paper was published, I had in my hands and weighed a bag which contained fourteen pounds of *Paludestrina*, quite clean and free from sand or any other shells, except a few examples of *Amnicola longinqua;* in other words *seven million three hundred and four* individuals. See also Nos. 34, 43, ante.

98. Fossil Shells of the John Day Region.—Science, N. S., Vol. 15, January 24, 1902, No. 369, pp. 153-154.

Helix (Epiphragmophora?) dubiosa nom. prov., *Pyramidula Le Contei*, and names provisionally *Limnaea maxima. Vide* previous paper, No. 48.

99. Unio Condoni in the John Day Beds.—Science (as above), March 7, 1902, p. 393.

Correction of omission in the preceding paper.

100. Helix var. circumcarinata and Pyramidula Elrodi.—Nautilus, Vol. 16, No. 6, pp. 61-62, Philadelphia, October, 1902.

101. Pyramidula elrodi and Epiphragmophora circumcarinata.—Nautilus, Vol. 16, No. 7, pp. 83-84, Philadelphia, November, 1902.

102. Mollusks occurring in Southern California.—Nautilus, Vol. 16, No. 12, pp. 133-134, Philadelphia, April, 1903.

Limax flavus, Limax maximus, Punctum conspectum in Los Angeles mentioned

103. Clam-orous Crows.—Nautilus, Vol. 17, No. 10, p. 120, Philadelphia, February, 1904.

Saxidomus giganteus carried by the crows and sometimes dropped on the roofs in Victoria, B. C.

104. Limax maximus and other Slugs in California.—Nautilus, Vol. 18, No. 3, pp. 34-36, Philadelphia, July, 1904. See also Pacific Rural Press, San Francisco, of about the same date.

Limax hewstoni, L. columbianus, L. californicus, and *L. maximus* mentioned, and remedies suggested for a pest of slugs.

105. The Cambridge Natural History: Errata corrected.—Nautilus, Vol. 18, No. 5, p. 58, Philadelphia, September, 1904.

106. Abalones and the Earthquake.—Nautilus, Vol. 20, No. 12, pp. 135-136, Philadelphia, April, 1907.

107. Fossil Mollusca from the John Day and Mascall Beds of Oregon.—Bull. Dep. Geology, Univ. California, Vol. 5, No. 3, pp. 67-70.

Helix (Epiphragmophora?) dubiosa nom. prov.; *Pyramidella (Oreohelix) Le Contei* n. s.; *Limnaea maxima* n. s.; described and figured.

108. On the Composition and Decomposition of Fresh-water Mussel Shells, with Notes and Queries.—Proc. Biol. Soc. Washington, June 12, 1907, Vol. 20, pp. 67-70.

Anodonta Nuttalliana and its varieties, of the West Coast, mentioned.

109. Among the Cephalopods.—Nautilus, Vol. 21, No. 2, p. 23, Philadelphia, June, 1907.

110. In re Cytherea petechialis of Carpenter's Mazatlan Catalogue.—Nautilus, Vol. 21, No. 3, p. 29, Philadelphia, July, 1907.

111. The U. S. Coast Survey Expedition to Alaska in the Year 1867.—Nautilus, Vol. 21, No. 3, pp. 29-31, Philadelphia, July, 1907.

COELENTERATA

112. Remarks on a New Alcyonoid Polyp, from Burrard's Inlet.—Proc. California Acad. Sci., Vol. 5, February 3, 1873; also separately, 8 pp.

113. Description of a new species of Alcyonoid Polyp, *Pavonaria Blakei*.—Mining and Scientific Press (San Francisco), August 9, 1873; also separately.

114. Description of a New Genus, *Verrillia*, and species, *V. Blakei*, of Alcyonoid Polyp.—Proc. California Acad. Sci., Vol. 5, August 18, 1873; Morning Call, San Francisco, August 12, 1873; Amer. Naturalist, Vol. 7, October, 1873, and Vol. 16, January, 1882.

115. Remarks suggested by Dr. J. E. Gray's paper on the "Stick Fish," in "Nature" [*Verrillia Blakei*], November 6, 1873.—Proc. California Acad. Sci., Vol. 5, March 16, 1874; also separately.

116. Verrillia Blakei or Halipteris Blakei.—Amer. Naturalist, January, 1882, pp. 55-56; also separately.

117. A new Virgularian Zoöphyte.—Mining and Scientific Press, San Francisco, October 13, 1883.

118. Description of a New Genus (*Radicipes*), and Species (*R. pleurocristatus*), of Alcyonoid Polyp, from Japanese waters, with remarks on the Structure and Habits of related forms, etc.—Proc. U. S. Nat. Mus., Vol. 6, 1883, pp. 96-101, and pl. 7.

119. Contributions to the Natural History of the Coelenterata; 4 pp., cover and title, Washington, D. C., October 26, 1889.

Historical Sketch and Bibliography of *Halipteris Blakei* and *Radicipes pleurocristatus*, with which copies of the previous papers were included under the same cover.

AGRICULTURE, ETC.

120. The Value of the Sugar Beet.—The Pacific, San Francisco, 1859.

If not the first, yet very nearly the first article suggesting the cultivation of the sugar beet as a profitable industry in California. No doubt too far ahead of the time. The first company was organized in 1869 and in November, 1870, the first beet sugar was made, the output the first season being 500,000 pounds. At the present date, 1903, the number of factories is *eight* with a capacity of 10,050 tons in twenty-four hours; "the capital invested in the factories will aggregate approximately $12,000,000, to which may be added as a working capital and that invested in land, enough to raise the total amount invested by the companies themselves in the industry to about $20,000,000." The population of the State being "1,485,053; the consumption of sugar estimated at 101,577,800

pounds and the production 160,000,000 pounds." (Geo. W. Shaw in Bulletin No. 149, Coll. of Agriculture, Univ. of California.)

121. A little more Lime.—The Pacific, San Francisco, 1859.

On the uses of Lime for various purposes in connection with farming.

122. Prolific Joint Corn.—California Horticulturist, November, 1873.

Notes of experiments with the above, and its value as compared with other varieties, for grain or fodder.

123. Ginseng the Chinese Panacea.—Cultivator's Guide, Sacramento, California, October, 1883.

Where found, its export value and possibilities in the way of trade and profitable culture.

124. The Sunflower.—Cultivator's Guide, Sacramento, California, December, 1883.

Its economic value in various ways indicated.

125. The Camass or Kamass.—Cultivator's Guide, Sacramento, California, January, 1884.

Camass esculenta the wild hyacinth of California and elsewhere; use by the Indians, etc.

126. Whitewashing Trees—uses of Lime, etc.—Cultivator's Guide, Sacramento, California, August, 1883.

Prevention of moss growth, sap-scald, and pestiferous insects.

127. Parasites in Domestic Animals.—Cultivator's Guide, Vol. 1, pp. 13-14, with figures, Sacramento, California, May 1, 1883.

The sheep rot, flukeworm, etc., their occurrence and metamorphoses.

128. On the care of young Fruit-trees, Orchards, etc.—Cultivator's Guide, Sacramento, California, June, 1883.

The selection of a site, planting out and protection against hot winds, extreme cold, and destructive animals.

129. Parasites in Drinking Water.—Cultivator's Guide, Sacramento, California, May, 1883.

130. Dracaena Australis for Basketry purposes, etc.—Pacific Rural Press, February 21, 1903.

The use of the long, slender tough leaves for basket-work, mats, and similar fabrics, is suggested.

FORESTRY, ETC.

131. On the Economic Value of certain Australian Forest Trees, and their cultivation in California.—Proc. California Acad. Sci., Vol. 4, 1872, pp. 236-241.

Also in Annual Report State Board of Health for 1872; the California Horticulturist and the California Farmer; fifteen hundred copies separately published in pamphlet form.

Review of the above in the *Nation*, New York, August 22, 1872, by Fred Law Olmsted. The foregoing, it was said at the time, gave an immediate impetus to the planting of these Australian species.

132. On the growth of certain California Forest Trees and the Meteorological inferences suggested thereby.

Read at the Cincinnati meeting of the American Forestry Association, April, 1882; printed separately, 8 pp. 8°.

Portions of above were read before the California Academy of Science, December 5, 1881.

133. Forest Tree Culture in California.—Review of the Decade, 1872-1882.

Read at the Cincinnati meeting of the American Forestry Association, April, 1882; printed separately, 12 pp., 8°.

This and the preceding published in the Report of the Association for 1882.

134. The Mulberry as a Useful and Ornamental Tree.—Cultivator's Guide, Sacramento, California, August, 1883.

Methods of propagation and care; good varieties mentioned.

135. The Oriental Sycamore as a street tree.—Pacific Rural Press, San Francisco, December 20, 1902.

136. Eucalypts cultivated in the United States.—Science, N. S., Vol. 17, No. 439, 1903, pp. 858-860.

A review and in part, criticism of Prof. A. J. McClatchie's "Eucalypts cultivated in the United States," Bull. No. 35, Bureau of Forestry, U. S. Dep. Agriculture, 1903.

137. Eucalypts in the Philippines.—Science, N. S., Vol. 18, No. 457, 1903, pp. 439-440.

ETHNOLOGY, ETC.

138. Remarks on Pre-historic Remains in Florida.—Proc. California Acad. Sci., Vol. 4, March 4, 1872; also separately.

139. The Pectens, or Scallop shells.—Overland Monthly, San Francisco, April, 1873, Vol. 10, pp. 342-345.

As referred to in History and Poetry; also remarks on their Anatomy.

140. Aboriginal Shell-money.—Proc. California Acad. Sci., Vol. 5, July 7, 1873, with plate.

141. Aboriginal Shell-money.—Overland Monthly, San Francisco, September, 1873, with figures.

Also Globus, Braunschweig, Germany, of about same date; without credit.

142. Aboriginal Shell-money.—Amer. Naturalist, Vol. 11, June, 1877, pp. 344-350, with figures and plate.

143. Aboriginal Shell Ornaments, and Mr. E. A. Barber's paper thereon.—Amer. Naturalist, Vol. 11, August, 1877, pp. 473-474.

144. On certain Aboriginal Implements, from Napa County, California.—Amer. Naturalist, March, 1882, pp. 203-209, 9 figures.

Read before the California Academy of Sciences, October 19, 1881.

145. Ethno-Conchology—a Study of Primitive Money.—Rep. U. S. Nat. Mus., 1887, pp. 297-334, pls. 1-9, and numerous text-figures.

The various American and Indo-Pacific species of shells used as money or a medium in trade in past and recent times are mentioned. A lengthy review of the above, 30 pp. by Ed. Jardin, was published in Vol. 17 (2d Series) of the Bulletin of the Société Academique of Brest, in 1892.

146. On the Nishinam Game of "Ha" and the Boston Game of "Props."—Amer. Anthropologist, October, 1890, pp. 353-358, with figures.

Read before the Anthropological Society of Washington, D. C. The Nishinam game was played with acorns, the Boston game with the marine shells, *Cypraea moneta*.

MISCELLANEOUS

147. Form of Seeds as a factor in Natural Selection in Plants.—Amer. Naturalist, July, 1879, pp. 411-420, several figures; also in Pacific Rural Press and mining and Scientific Press, San Francisco, of about same date.

Read before the California Academy of Sciences, July, 1879.

The changes in the Flora between the years 1858 and 1879 in the neighborhood of Berkeley, California, are pointed out.

The botanical forms mentioned are *Brassica nigra, Erodium cicutarium* and *E. moschatum, Geranium maculatum, Hordeum maritimum, Medicago denticulata, Centaurea melitensis, C. solstialis, Madia sativa,* etc.

148. On the Botanical relations of *Physianthus albens,* the structure of its flowers, and their peculiarities as an Insect trap.—Pacific Rural Press, San Francisco, November, 1881, with several figures, under the title "A Moth-catching Plant."

Previously read before the California Academy of Sciences.

149. The Acorn-storing habit of the California Woodpecker, Melanerpes formicivorus.—Amer. Naturalist, May, 1882, pp. 353-357; also separately.

150. Instances of the effect of Musical Sounds on Animals.—Amer. Naturalist, Vol. 24, January, February and March, 1890. Also separately, 23 pp., cover and title.

Read before the Biological Society of Washington, D. C., May 1, 1886.

A lengthy notice of above by Catherine C. Hopley, in the Globe, London, England, April 14, 1890.

151. The Distribution of Species.—Forest and Stream, May 13, 1886.

Read before the American Fisheries Society, April 14, 1886.

152. On certain Parasites, Commensals and Domiciliares in the Pearl oysters, Meleagrinae.—Ann. Rep. Smithsonian Inst. for 1886, Part 1, pp. 339-344, pls. 1, 3, 1889.

153. Araujia albens as a Moth-trap.—Amer. Naturalist, Vol. 21, June, 1887, pp. 501-507, with numerous figures.

Read before the Biological Society of Washington, D. C., February 19, 1887.

The names of the species of *Lepidoptera* and other insects entrapped are given.

154. On Xylophagous Marine Animals.—California Horticulturist, etc., May, 1873, with figures.

155. Zoölogical Scraps from a Californian Notebook.—Cultivator's Guide, Sacramento, California, July, 1883.

White beavers; a squealing Toad; Protective coloration of the Horned Toads; Sandhill Cranes, mentioned.

156. On Accidentally introduced forms of Animals.—West American Scientist, February, 1891, pp. 107-109.

GENERA AND SPECIES NAMED FOR ROBERT EDWARDS CARTER STEARNS BY THE AUTHORS

Cetacean: Grampus Stearnsii DALL.
Fish: Roncador Stearnsii STEINDACHNER.
Recent Mollusks:
Voluta (Scaphella) Stearnsii DALL.
Cylindrella Stearnsii ARANGO.
Lamellaria Stearnsii DALL.
Unio Stearnsiana WRIGHT.
Aesopus Stearnsii TRYON.
Helix Stearnsiana GABB.
Microphysa Stearnsii BLAND.
Bulimus (Anctus?) Stearnsianus PILSBRY.
Callocardia Stearnsii DALL.
Periploma Stearnsii DALL.
Mytilus Stearnsi PILSBRY and RAYMOND.
Paludestrina Stearnsiana PILSBRY.
Sportella Stearnsii DALL.
Ischnochiton Stearnsii DALL (1902).
Venericardia (Cyclocardia) Stearnsii DALL (1902).
Fossil Mollusks:
Scala Stearnsii DALL.
Bulimus Stearnsii DALL.
Vorticifex Stearnsii WHITE, and
Stearnsia, WHITE, for a Generic form of Cretaceous Mollusk.
Coral: Paracyathus Stearnsii VERRILL.

SMITHSONIAN MISCELLANEOUS COLLECTIONS

VOLUME 56, NUMBER 19

THE SILVER DISK PYRHELIOMETER

(WITH ONE PLATE)

BY

C. G. ABBOT

Director, Astrophysical Observatory of the Smithsonian Institution

(PUBLICATION 2008)

CITY OF WASHINGTON

PUBLISHED BY THE SMITHSONIAN INSTITUTION

March 31, 1911

WASHINGTON, D. C.
PRESS OF JUDD & DETWEILER, INC.
1911

THE SILVER DISK PYRHELIOMETER

By C. G. ABBOT

Director, Astrophysical Observatory of the Smithsonian Institution

(With One Plate)

In 1902 the writer designed a mercury pyrheliometer based on the fundamental device of Pouillet, as modified by Tyndall. This instrument was described in the Annals of the Astrophysical Observatory of the Smithsonian Institution, volume 2. As the measurements have gone on at Washington, Mount Wilson, and Mount Whitney for the determination of values of the solar constant of radiation, various alterations have seemed desirable, which led in 1909 to the form of instrument here described.

The silver disk, *a*, shown in cross-section, is bored radially with a hole to admit the cylindrical bulb of a thermometer, *b*. The hole in the disk has a thin lining of steel, so that a small quantity of mercury may be introduced without alloying the silver, in order to make a good heat conduction between the silver disk and the thermometer bulb. A soft cord soaked in shellac is forced down at the mouth of the hole to prevent the escape of mercury, and a ring of Chatterton wax is sealed over the outside of the cord to make the closure more perfect.

The thermometer, *b*, is bent at a right angle, as shown, in order to make the instrument more compact and less fragile. A nickeled brass tube (shown partly cut away in the figure) supports and protects the thermometer. A slot is cut in the right-hand side of the support tube throughout almost its whole length to permit the reading of the thermometer. At the top of the support tube a short piece is removable, in order that heat may be applied to the overflow bulb of the thermometer, to dislodge mercury which sometimes collects there during transportation. The thermometer is graduated to tenths of degrees centigrade from $-15°$ C. to $+50°$ C. Two points, $0°$ and $+50°$, are first marked on the stem by the makers, and then the thermometer is graduated by equal linear intervals without regard to the variations of cross-section of bore of the stem. Before insertion in the instrument, a careful calibration of the thermometer stem is made.

The silver disk, *a*, is enclosed by a copper cylindrical box, *c*, halved together for convenience in construction. Three small steel wires, not shown in the figure, support the silver disk. These wires lie in the plane of the center of the disk at 120° intervals apart. Midway between them are three brass screws, not shown, which may be screwed through the walls of the box, *c*, up to their heads. These screws in that position clamp the silver disk tightly. Their purpose is to prevent the breakage of the thermometer if jarred during transportation. These screws must be loosened during observations.

The copper box, *c*, is enclosed by a wooden box, *d*, to protect the instrument from temperature changes. This box is also halved together and fastened by long wood-screws, one of which is seen near the letter, *d*, in the figure.

Sunlight may be admitted through the tube, *e*. This tube is provided with a number of diaphragms, f_1 f_2 f_3, having circular apertures. The aperture, f_3, nearest the silver disk is slightly smaller than the others, and slightly smaller than the disk itself. Thus it limits the cross-section of the sunbeam whose intensity is to be measured. The entire interior of the tube, *e*, the box, *c*, and the silver disk, *a*, are painted dead black with lamp-black mixed in alcohol, with a little shellac added to cause the lamp-black to stick. To secure a fine, even coat, the mixture is filtered through cheesecloth before applying, and on the disk it is warmed with an alcohol lamp until the brush marks disappear.

A rotatable shutter, *g*, with three nickeled parallel metal plates, *h h h*, is provided for cutting off the sunlight as desired. The top of the tube, *e*, carries a screen, *k*, large enough to shade the wooden box, *d*. This screen also supports the thermometer tube, and the axis of the exposing shutter just mentioned. A small hole in the part which supports the thermometer admits a little guiding beam of sunlight, *i*, whose use is to assure the observer that the instrument points towards the sun.

The pyrheliometer is carried upon an equatorial stand, as shown in the figure. A worm and wheel mechanism is provided for following the sun. No clockwork is needed, as it is sufficient for the observer to move the worm slightly two or three times a minute.

The purpose of the silver disk pyrheliometer is merely to furnish readings proportional to the intensity of radiation of the sun, and comparable one with another at all times and places, but not to furnish independent means of reducing these readings to true heat

units. Pouillet, it is true, determined the dimensions of his pyrheliometer, and from them reduced his results approximately to calories per square centimeter per minute. But owing to several uncertainties not necessary to mention here, it is not practicable to achieve sufficient accuracy in such standardizations of pyrheliometers of this type. They must therefore be regarded as secondary instruments, useful only for relative readings, unless standardized by comparison with true standard pyrheliometers. Such standardizations have been made at the Astrophysical Observatory.[1]

Regarding the silver disk pyrheliometers as secondary instruments, an abridged method of reading is possible, which materially reduces the labor of observation and reduction. In ordinary calorimetry the thermometer is read as frequently as possible, often at 10 or 20 second intervals, in order that a graphical representation of the whole march of temperatures may be made. In this way the most exact determination is possible of the rate of rise of temperature due to the source of heat itself, irrespective of cooling or warming due to the surroundings. In the use of the pyrheliometer as a secondary instrument the true value of the rate of rise of temperature due to solar heating is not material. If a simplified method of observation can furnish results which are under all circumstances greater or smaller by a constant fraction than the true rate of rise, such results are equally as valuable as the true ones would be. For the standardization constant of the instrument corrects such errors. By numerous experiments it has been shown that the short method of reading the instrument to be described below satisfies the condition just explained, well within the error of the observations, hence it has been adopted.

In order to promote pyrheliometric measurements of the solar radiation in other parts of the world, with instruments whose indications are quite comparable, Secretary Walcott loaned, in 1910, three silver disk instruments which were constructed at the cost of the Hodgkins fund and carefully standardized. These instruments were sent to Messrs. M. A. Rykatchew of St. Petersburg, J. Violle of Paris, and C. Chistoni of Italy. Unfortunately the first two mentioned were broken in transportation, but they have since been replaced. In the latest sendings the pyrheliometer proper is wrapped at its heavy end in cotton, and tied into its box in such a way that the projecting thermometer is wholly free, and could not possibly come in contact with any parts of the box. This box is enclosed in

[1] See Abbot and Aldrich: Astrophysical Journal, March, 1911.

a soldered tin case. This, in turn, is surrounded by a larger wooden box, having ten spiral chair-seat springs fastened within, so as to give elastic support to the inner case. To prevent too much movement of the inner case, wads of excelsior are put between the boxes at the eight corners. To prevent severe jarring of the outside box, wads of excelsior in canvas are also tacked outside the outer box at its eight corners.

Besides the three pyrheliometers mentioned, two have been sold by the Institution to the United States Weather Bureau and to the Physical Laboratory of the Agricultural Department of the United States. Three others are being prepared by request for use in South America—one at Arequipa, Peru, two in Argentina.

With each instrument is sent out a calibration sheet, and also the following:

Directions for Using the Abbot Silver Disk Pyrheliometer

Setting Up

The pyrheliometer is in the long box; the mounting in the cubical box.

1. If the mercury column of the thermometer is broken, remove the little screw at the side near the upper end of the nickel-plated tube, and take off the upper portion of the tube. Then heat the exposed stem cavity of the thermometer gently in a smoky flame (a match flame is good) until the mercury is expelled from the cavity. Then, holding the thermometer vertical, shake the instrument repeatedly with a downward jerk until the mercury columns join.

2. Remove the two little ivory plugs (using pliers if necessary) and unscrew the two brass screws under them, and also unscrew the third similar screw seen through the trunnion on the other side of the case. About three complete turns of each screw is proper. Insert the two ivory plugs. *When packing the instrument again for a journey, screw in the three screws as far as they will go.* Their purpose is to clamp the silver disk to protect the thermometer during transportation.

3. Unscrew the two pivots from the sides of the ring of the mounting, insert the pyrheliometer so that the thermometer is *not* next to the worm wheel, and screw in the pivots.

4. Unclamp the half ring and set the polar axis approximately for the latitude of the place. The thermometer should be next to the *upper* end of the axis.

Adjustments

5. For quick adjustment in right ascension guide the pyrheliometer with one hand and loosen the lower right-hand milled screw (as seen from the upper end of the polar axis). The worm may then be lowered out of engagement with the wheel and the change made.

6. To follow the sun, adjust in right ascension and declination until the sun shining through the little hole in the upper plate forms its image on the scratched spot on the nickeled piece below. When exposing to solar radiation rotate the worm screw a little (about once every half minute) to follow the sun.

7. When about to observe, push aside the cover, leaving only the shutter to shade the silver disk. When through with each series of readings, close the cover to keep out dust.

Observations

8. When reading the thermometer the observer should hold his head so that the reflection of each dark line of the scale near the degree to be observed, as seen in the mercury thread, is coincident with the corresponding dark line. This prevents parallactic errors of reading.

9. Having adjusted the instrument to point at the sun and opened the cover, read the thermometer exactly at 20 seconds after the beginning of the first minute. Read again after 100 seconds, or at the beginning of the third minute, and immediately after reading open the shutter to expose to the sun. Note that the instrument is then correctly pointed. After 20 seconds read again. After 100 seconds more (during which the pointing is corrected frequently), or at the beginning of the fifth minute read again, and immediately close the shutter. After 20 seconds read again. After 100 seconds read again, or at the beginning of the seventh minute, and immediately open the shutter. Continue the readings in the above order, as long as desired. Readings should be made within 1/5 second of the prescribed time. Hold the watch directly opposite the degree to be observed, and close to the thermometer. Read the hundredths of degrees first, the degree itself afterward.

10. For example:

Reading.....	1	2	3	4	5	6
Time.....	$11^h55^m20^s$	57^m00^s	57^m20^s	59^m00^s	59^m20^s	$0^h01^m00^s$
Reading.....	15°.12	14°.25	14°.80	17°.58	17°.36	16°.09
Condition.....	Shaded		Exposed		Shaded	

Reading.....	7	8	9	10
Time.....	01^m20^s	03^m00^s	03^m20^s	05^m00^s
Reading.....	16°.58	18°.99	18°.75	17°.29
Condition.....	Exposed		Shaded	

Air temperature 15°. Pyrheliometer "S. I. Q."

Reductions

11. Subtract readings (2) from (1); (3) from (4); (6) from (5); (7) from (8); (10) from (9).

12. Take the algebraic means

$$\frac{(1)-(2)+(5)-(6)}{2}; \quad \frac{(5)-(6)+(9)-(10)}{2};$$

and to them add [(4)—(3)] and [(8)—(7)] respectively.

13. Call the results above R_1 and R_2. Find roughly the mean temperatures T_1 and T_2 during the intervals of exposure (3) to (4) and (7) to (8).

14. Add to R_1 and R_2 the percentage corrections for graduation furnished with the instrument, then, after correcting, add to R_1, $K[(T_1 - 30°)R_1]$ and to R_2 add $K[T_2 - 30°)R_2]$. K is a constant furnished with the instrument. If the prevailing temperature of the air differs much from 20°, add 0.0014R for each 10° the air temperature falls below 20°. The results (which we will call R'_1 and R'_2) are the final rates of rise per 100 seconds during the exposures (3) to (4) and (7) to (8) as reduced to the standard bulb temperature of 30°, and standard stem temperature of 20°.

15. (Note.) The approximate method of procedure stated in (12) and (14) is much easier than the exact method, and having been found by experiments to yield closely comparable results under all circumstances of use, within the error of measurement, it has been adopted, and the standardization of the instrument is made by this method.

16. To reduce the results R'_1 and R'_2 to standard calories per square centimeter per minute, or to the scale provisionally used up to 1910 by the Smithsonian Institution, multiply by the factors furnished from the Smithsonian Institution with each instrument.

17. Under favorable circumstances an experienced observer can read to a probable error of $\frac{3}{10}$ per cent for a single reading. The sample readings here given differ more than this, for they were made at sealevel with variable sky.

18. Example of reduction:

Number	1	2	3	4	5	6	7	8	9	10
Reading	15°.12	14°.25	14°.80	17°.58	17°.36	16°.09	16°.58	18°.99	18°.75	17°.49
Differences	0°.87		2°.780		1°.27		2°.410		1°.46	
Cooling correction			1°.070				1°.365			
R_1 and R_2			3°.850				3°.775			
T_1 and T_2			16°.2				17°.8			
Scale correction	$-0.0020R_1=$		−0°.008		$-0.0022R_2=$		−0°.008			
KR (T−30°)	$-(0.0011)(13.8)R_1=$		−0°.058		$-(0.0011)(12.2)R_2=$		−0°.051			
Air correction	$+0.0007R_1=$		+0°.003				+0°.003			
R^1_1 and R^1_2			3°.787				3°.719			

Several questions have arisen regarding the accuracy of the silver disk pyrheliometer:

1. As to the effect of variations of the light of the sky, it might seem that since the pyrheliometer is exposed to about 80° of solid angle, of which the sun occupies only about 0.°2, the sky light might be quite considerable. To test this question a screen which limited the solid angle to 5° was fixed to one instrument, and another instrument with the usual arrangements was compared with it at Washington. No alteration of the relative readings due to the use of the screen could be found on a very clear day. On another day, less clear, a change of relative readings of about 0.5 per cent was found. On a very poor day the effect may reach 1 or even 2 per cent. On Mount Wilson the sky is so clear that its effect would be negligible.

2. As regards the inclination of the instrument, experiments were made by affixing a mirror to one pyrheliometer, so that the sun at about 45° from the zenith could be observed in two positions, vertical and horizontal, of the instrument, without shifting the mirror with respect to the pyrheliometer. Thus equipped, the pyrheliometer was compared with a second, read in the usual manner. No alteration of the relative readings could be found depending on the inclination.

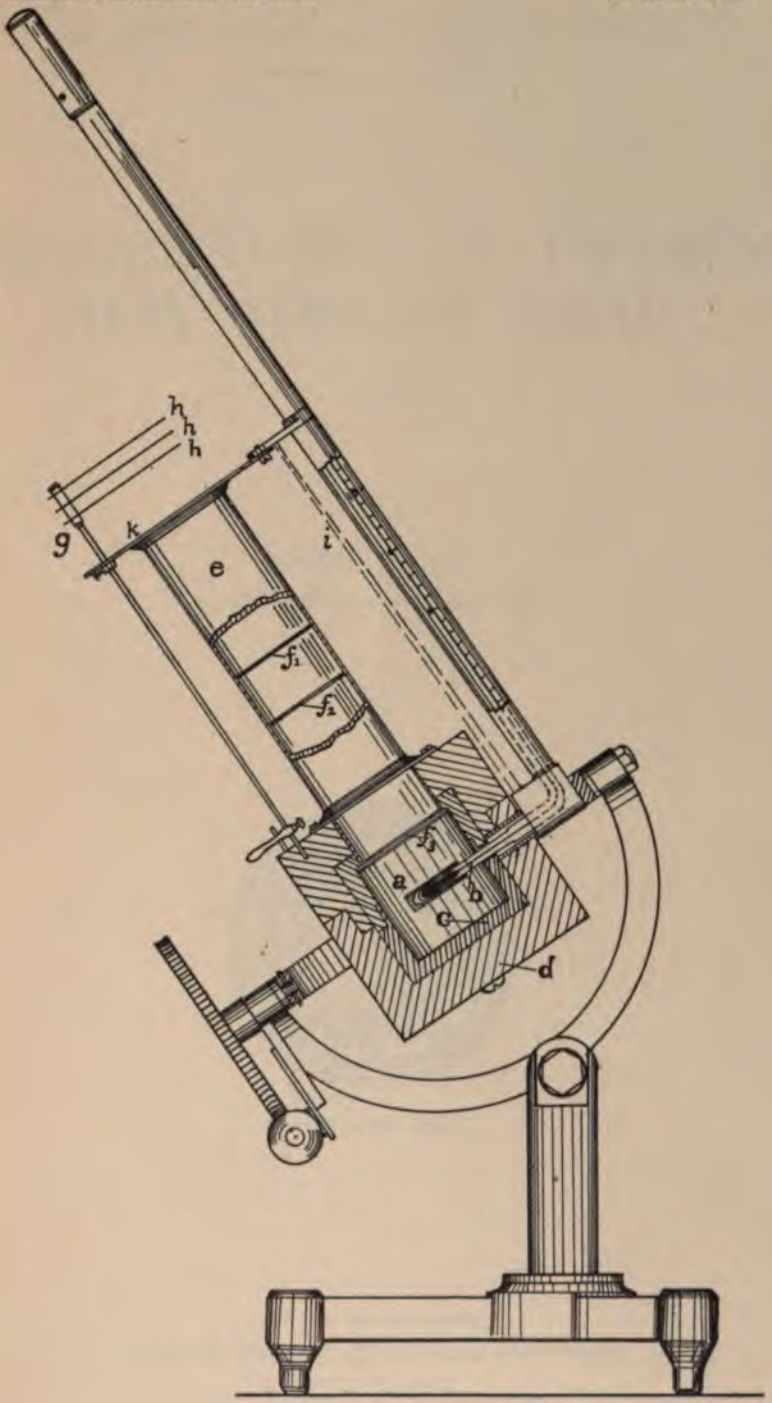
3. As regards atmospheric pressure, a metal box was fitted to one pyrheliometer and a glass plate fixed over the tube for admitting sun rays, so that the air could be exhausted from the interior of the pyrheliometer. Comparisons were made at atmospheric pressure, and at about 1/760 of atmospheric pressure, with another instrument read as usual. No changes of the relative readings depending on air pressure could be discerned.

4. As regards age of the blackened surface of the *silver disk*, we have not very long-continued records. But a *copper disk* instrument has been employed on Mount Wilson since the spring of 1906, and has been many times compared with other copper disk instruments there. It has been several times cleaned and re-blackened. There is no evidence that changes as great as 1 per cent have ever occurred due to defects in the blackening. The instrument appears now to have the same relative readings compared with another instrument at Washington which has been unchanged and seldom used since 1906, that subsisted between them five years ago. Another copper disk instrument was loaned in 1907 to the Weather Bureau. Its blackening has been unchanged, and it now (1911)

gives the same relative readings compared with the one at the Astrophysical Observatory that it did in 1907.

5. As regards accidental error of observation, persons with good eyesight and experience in observing appear to read with a probable error, for a single determination, at high sun, not exceeding 3/10 per cent. As a single determination depends on six readings, and the rise of temperature determined is only about 3°, this requires a probable error of single readings of temperature not exceeding 0.°005, or 1/20 division of the scale. It seems almost incredible that this degree of accuracy should usually be attained, but comparisons of instruments by two observers simultaneously, if made under excellent sky conditions, so indicate.

A silver disk pyrheliometer ready for shipment, including standardization and boxing, costs the Smithsonian Institution about $100. While it is not desired to manufacture them extensively, the Institution has in several instances consented to prepare and sell them. In cases where this evidently will tend to promote valuable and regular series of solar observations, the Institution is prepared to furnish silver disk pyrheliometers at the price above stated.



ABBOT SILVER DISK PYRHELIOMETER

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 56, NUMBER 20

DESCRIPTIONS OF FIFTEEN NEW AFRICAN BIRDS

BY

EDGAR A. MEARNS
Associate in Zoölogy, U. S. National Museum

(PUBLICATION 2010)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
APRIL 17, 1911

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

DESCRIPTIONS OF FIFTEEN NEW AFRICAN BIRDS

By EDGAR A. MEARNS

ASSOCIATE IN ZOÖLOGY, UNITED STATES NATIONAL MUSEUM

This paper is the fourteenth dealing with the results of the Smithsonian African Expedition under the direction of Col. Theodore Roosevelt. It embraces descriptions of fifteen new species and subspecies of birds, ten of which were discovered by members of the expedition.

Pternistes leucoscepus (G. R. Gray), a plastic species of the East African region, has been divided into several subspecies in the northern portion of its range. Hitherto, the form found over much of British and German East Africa has been known as *Pternistes leucoscepus infuscatus* (Cabanis), but in the series of thirty specimens from this region in the collection of the United States National Museum, there are two undescribed subspecies from Mount Kenia, and Mount Kilimanjaro, respectively. These are the darkest forms of the species, and have a preponderance of chestnut color on the under parts.

Cabanis's description and very satisfactory colored plate (v. d. Decken's Reise, 1869, pl. 14) show that the form *infuscatus*, described by him from Lake Jipe, German East Africa, is the widely ranging plains race, and neither of the mountain forms described below, from both of which it may be readily distinguished by having the tail and wings distinctly cross-banded, and the dark centers of the long feathers of the flanks undivided by a central white shaft-stripe.

PTERNISTES LEUCOSCEPUS KENIENSIS, new subspecies

Mount Kenia Bare-throated Spurfowl

Type-specimen.—Adult male. Cat. No. 214721, U. S. N. M. Collected on the west slope of Mount Kenia, on the N'joro or Kasorongai River, 6500 feet, British East Africa, October 18, 1909, by Edgar A. Mearns. Original number, 17164.

Characters.—Differs from *Pternistes leucoscepus infuscatus* in its generally darker coloration; in the absence of transverse bars on the wings and tail, which instead of being barred are minutely speckled

and vermiculated; in the much narrower white borders of the feathers of breast and sides, those of the flanks having white shaft-stripes; and in having the thighs and crissum darker and without pure white edges. Adult males have the iris brown; bill olivaceous brown, orange at base below; feet and claws black; naked sides of face and chin light red; throat bright yellow. Females are similar, but with less orange at base of bill below.

Measurements of type-specimen (adult male).—Wing, 204 mm.; tail, 105; exposed culmen (chord), 33; tarsus, 67; longest spur, 22.

Material.—Twenty specimens are referred to this subspecies.

Remarks.—Thirteen specimens taken around the base of Mount Kenia, at an altitude of 6000 to 7000 feet are typical *keniensis.* Seven specimens from Fort Hall and Saba Saba, at altitudes of 3900 and 4000 feet, are intergrades between *infuscatus* and *keniensis.* Specimens from Wambugu, Kapiti Plains, Ulukenia Hills, and the Southern N'Guaso Nyiro River in the Sotik District are all typical *infuscatus.*

PTERNISTES LEUCOSCEPUS KILIMENSIS, new subspecies

Mount Kilimanjaro Bare-throated Spurfowl

Type-specimen.—Adult female. Cat. No. 117817, U. S. N. M. Collected in the Mount Kilimanjaro Region, East Africa, 1888-'89, by Dr. W. L. Abbott.

Characters.—This is the extreme of the dark forms of *Pternistes leucoscepus,* and differs from *Pternistes leucoscepus infuscatus* in much the same way as does *keniensis.* Its closest affinity appears to be with *keniensis,* from which it differs in having a general castaneous tone of coloration; the light specklings of the wings and tail and the shaft-streaks of the mantle and wing-coverts are chestnut or rust color instead of grayish or buffy white; the concealed pale markings of the wing-quills are decidedly rusty instead of nearly white; the white edgings to the feathers of the breast and sides are obsolete except upon the posterior flanks, and these parts have the chestnut color extending to the subtriangular white spots at the tips of the feathers.

Measurements of type-specimen (*adult female*).—Wing, 181 mm.; tail, 82; exposed culmen (chord), 32; tarsus, 55.

Material.—Two specimens (one female and one unsexed) collected by Dr. W. L. Abbott.

Remarks.—The size is quite uniform in the three forms under consideration.

FRANCOLINUS GRISESCENS, new species

Grayish Francolin

Type-specimen.—Adult female. Cat. No. 216223, U. S. N. M. Collected at Lokko Zegga, Uganda, Africa, February 13, 1910, by Edgar A. Mearns. Original number, 18407.

Characters.—Allied to *Francolinus clappertoni* Children, but apparently much smaller than the subspecies *gedgii* and *heuglini;* females without chestnut markings; crown and ear-coverts prouts brown; feathers of upper side of neck and mantle black or brownish black, bordered with white except at the tips, and with narrow white shaft-stripes posteriorly; general color of remainder of upper parts grayish drab; feathers of back and rump with sagittate black markings and pale shaft-stripes; outer surface of wings spotted and irregularly cross-banded with grayish rusty white; wing-quills dark brown, cross-banded with rusty white and without longitudinal markings; tail brownish black, narrowly cross-banded with grayish white or rusty white; sides of head and neck buffy white, narrowly striped with black; chin and throat plain buffy white; remainder of under parts pale buff with brownish black markings, those of the chest V-shaped, with guttate extremities on the lower breast and sides, becoming oval or elliptical and sparse on the abdomen, and irregularly hastate on the posterior flanks and upper thighs; under tail-coverts buffy white, broadly banded with dark brown.

Measurements of type-specimen (adult female).—Wing, 155 mm.; tail, 73; exposed culmen (chord), 26; tarsus, 47.

Material.—Six females from the upper Bahr el Jebel, near Lake Albert.

FRANCOLINUS GRANTII DELUTESCENS, new subspecies

Kasorongai Francolin

Type-specimen.—Adult male. Cat. No. 214748, U. S. N. M. Collected on a high, wooded hill at the base of Mount Kenia, west of the camp on the N'joro or Kasorongai River, altitude 7000 feet, British East Africa, October 19, 1909, by Edgar A. Mearns. Original number, 17172.

Characters.—Most closely related to *Francolinus grantii grantii* Hartlaub and *Francolinus grantii ochrogaster* (Hartlaub). From the latter it may at once be distinguished by its considerably larger size and much less ochraceous coloration. It is more closely related to typical *grantii;* compared with that bird it is seen that the size is

slightly greater; the general color is much more grayish, especially on the back, rump, and chest: the belly and crissum are much less ochraceous; the neck-collar of subtriangular chestnut markings is narrower, with the spots smaller; the upper parts are less rufescent—more olivaceous than reddish brown; the white shaft-streaks of the upper parts are much narrower and more broadly bordered with black; the crown is darker, with the bases of the feathers black instead of brown. Females have the upper parts much more abundantly vermiculated, cross-banded, and dotted with black than in the females of typical *grantii* or *ochrogaster*.

Comparative measurements.—Average of two adult males of *Francolinus grantii delutescens:* Wing, 146 mm.; tail, 87; exposed culmen (chord), 20; tarsus, 41.

Average of two adult males of *Francolinus grantii grantii:* Wing, 143 mm.; tail, 90; exposed culmen (chord), 19.5; tarsus, 42.

Average of two adult males of *Francolinus grantii ochrogaster:* Wing, 135; tail, 86; exposed culmen (chord), 19; tarsus, 40.

FRANCOLINUS SCHUETTI ZAPPEYI, new subspecies

Zappey's Francolin

Type-specimen.—Adult male. Cat. No. 56122, Museum of Comparative Zoölogy, Cambridge, Massachusetts. Collected on the east shore of Lake Victoria, in British East Africa, October 3, 1910, by Walter R. Zappey.

Characters.—Most closely related to *Francolinus schuetti kapitensis* Mearns, the palest and grayest of the four recognized subspecies of *Francolinus schuetti* Cabanis, from which it may be readily distinguished by the very broad pale edging to the feathers of the under parts and the absence of coarse markings on the upper parts; the crown is grayer and less brownish olive; the back and scapulars are much the same, but with clearer gray margins to the feathers; the general color of the lower back, rump, and upper tail-coverts is more olive brown, with the vermiculations obsolete; the outer webs of the outer primaries are plain dark brown; the rectrices are warm brown, with scarcely a trace of vermiculations; the feathers of the chest are grayish hair brown with apical shaft-stripes of broccoli brown, not flecked with black near the shafts; the feathers of the lower breast, upper abdomen, and flanks are soiled grayish white with shaft-stripes of hair brown; the under tail-coverts are hair brown broadly bordered with buffy white. "Bill and tarsi deep orange." (Zappey.)

Measurements of type (adult male).—Wing, 177 mm.; tail, 90; exposed culmen, 25; tarsus, 52; middle toe (without claw), 42; longest spur, 14.

Remarks.—The right foot has two developed spurs, the left only one.

PTILOPACHUS FUSCUS KENIENSIS, new subspecies

Mount Kenia Stone-Pheasant

Type-specimen.—Adult male. Cat. No. 56123, Museum of Comparative Zoölogy, Cambridge, Massachusetts. Collected on hills west of Mount Kenia, British East Africa, July 28, 1909, by Dr. Glover M. Allen.

Characters.—Most closely related to *Ptilopachus fuscus florentiæ*, from Gessema, British East Africa, but differing in having the coloration darker; the breast is pale buff; the feathers of the flanks are very narrowly barred with chestnut; the nape and mantle are without any chestnut whatever. "Eye-ring red; legs pink." (Allen.)

Measurements of type (adult male).—Wing, 120 mm.; tail, 78; culmen, 15; tarsus, 31.

Average measurements of two adult female topotypes.—Wing, 119 mm.; tail, 87; culmen (chord), 16; tarsus, 30.5.

TURNIX SYLVATICA ALLENI, new subspecies

Allen's Hemipode

Type-specimen.—Adult male. Cat. No. 56126, Museum of Comparative Zoölogy, Cambridge, Massachusetts. Collected on plains of the N'Guaso Nyiro River, near Mount Kenia, British East Africa, July 20, 1909, by Dr. Glover M. Allen.

Characters.—Most closely related to *Turnix sylvatica lepurana* (Smith), from which it differs in its more intense coloration; the brown of the crown, mantle, rump, and tail is much darker, and the dark markings are much larger and blacker; the rust color of the chest is also much stronger; all of the dark markings are increased in area and intensity.

Measurements of type (adult male).—Wing, 70 mm.; tail, 34; culmen (chord), 12; tarsus, 21.

Measurements of adult male of Turnix sylvaticus lepurana (Cat. No. 117841, U. S. N. M., Kahé, south side of Mount Kilimanjaro).—Wing, 70 mm.; tail, 34; culmen (chord), 13; tarsus, 21.5.

XANTHOPHILUS BOJERI ALLENI, new subspecies

Allen's Golden Weaver

Type-specimen.—Adult male. Cat. No. 56117, Museum of Comparative Zoölogy, Cambridge Massachusetts. Collected on the Miru River, near Mount Kenia, British East Africa, August 13, 1909, by Dr. Glover M. Allen.

Characters.—Adult male similar to that of *Xanthophilus bojeri bojeri* (Finsch and Hartlaub), but larger and slightly darker, with the bill slightly stouter, and having the upper contour more convex; the upper parts are less yellow because more heavily washed with olive-green; the wings and tail are darker above and below; the head and under parts are distinguishable from those of *bojeri* only by a slight intensification of the orange and yellow colors.

Female with upper parts darker, more greenish gray, without warm brown tints.

Measurements of type (adult male).—Wing, 79 mm.; tail, 59; culmen (chord), 16; tarsus, 22.5.

Average measurements of three adult male topotypes.—Wing, 78.7 mm.; tail, 59; culmen (chord), 16.1; tarsus, 22.5.

Measurements of adult female topotype (Cat. No. 56118, Mus. Comp. Zoöl.).—Wing, 69 mm.; tail, 52; culmen (chord), 15.2; tarsus, 20.2.

Measurements of Xanthophilus bojeri bojeri.—Average of nine adult males from Changamwe and Mombasa, on the coast of British East Africa: Wing, 72.3 mm.; tail, 54; culmen (chord), 16; tarsus, 21.1. Average of three adult females (same localities): Wing, 65.9 mm.; tail, 51; culmen (chord), 15.2; tarsus, 20.2.

Material.—Five specimens from N'Guaso Nyiro and the Miru Rivers.

URÆGINTHUS BENGALUS BRUNNEIGULARIS, new subspecies

Brown-chinned Ruby-cheeked Cordon-bleu

Type-specimen.—Adult female. Cat. No. 215922, U. S. N. M. Collected at Wambugu, 5500 feet, British East Africa, October 23, 1909, by Edgar A. Mearns. Original number, 17309.

Characters.—Similar to *Urœginthus bengalus schoensis* Neumann, but averaging slightly smaller; the female has the side of head and chin brown instead of blue, though there may be a trace of blue next to the mandible.

Measurements of type (adult female).—Wing, 54 mm.; tail, 58; culmen (chord), 9.5; tarsus, 15.

Remarks.—All adult females of the races of *Uræginthus bengalus* found in the N'Guaso Nyiro region, northwest of Mount Kenia, British East Africa, and in the valley of the Upper White Nile, have the sides of the face and chin blue. One female (Cat. No. 213779, U. S. N. M.) from Juja Farm, Athi River, British East Africa, May 19, 1909, is intermediate with respect to the coloration of the chin and sides of head, both of which are brown, mixed with blue; but the bill agrees in size with that of *brunneigularis,* which is about one millimeter shorter than that of *schoensis.*

Average measurements of nine adult males.—Wing, 52.2 mm.; tail, 58; culmen (chord), 9.8; tarsus, 14.3.

Average measurements of twelve adult females.—Wing, 51.5 mm.; tail, 53.5; culmen (chord), 9.5; tarsus, 14.3.

PYCNONOTUS LAYARDI Gurney

Layard's Yellow-vented Bulbul

Pycnonotus layardi GURNEY, Ibis, 1879, p. 390 (Rustenburg, Transvaal).

The typical form, *Pycnonotus layardi layardi,* inhabits the eastern districts of the Cape region of South Africa. In the coast region of German and British East Africa it merges into the subspecies *micrus,* and, farther north, and west to the Nile Valley, into several recognizable subspecies, three of which are here described as new.

PYCNONOTUS LAYARDI FAYI, new subspecies

Fay's Bulbul

Type-specimen.—Adult male. Cat. No. 214391, U. S. N. M. Collected at Fay's Farm, at N'jabini, British East Africa, altitude 8000 feet, August 11, 1909, by Edgar A. Mearns. Original number, 16537.

Characters.—Similar to *Pycnonotus layardi micrus* Oberholser in pattern and coloration, but nearly as large as *Pycnonotus layardi layardi,* from which it differs in being more darkly colored, with dark centers to the feathers of the mantle, and a tendency to striping of the lower breast instead of the softly-blended coloration of *layardi. Micrus* is much paler as well as smaller than *fayi.*

Nestlings, ready for flight, have the head blackish brown; the wings and tail dark brown; the remaining upper parts bistre; the

lower breast and abdomen buffy white; the crissum and upper tail-coverts sulphur yellow; and the sides pale brown.

Measurements of type (adult male).—Wing, 98 mm.; tail, 88; exposed culmen, 16; tarsus, 21.6.

Material.—Twenty-one specimens from western British East Africa.

Remarks.—This form extends from the Kapiti Plains west to Lake Victoria, in British East Africa. *Pycnonotus layardi micrus* ranges from the coasts of German and British East Africa west to the Kapiti Plains region, where it intergrades with *fayi* and also with the form described below.

PYCNONOTUS LAYARDI PEASEI, new subspecies

Kitunga Bulbul

Type-specimen.—Adult male. Cat. No. 213532, U. S. N. M. Collected at Sir Alfred Pease's Farm, Kitunga, British East Africa, altitude 6500 feet, May 2, 1909, by Edgar A. Mearns. Original number, 15656.

Characters.—Most closely related to *Pycnonotus layardi dodsoni* Sharpe, from Somaliland, but larger (see subjoined table of comparative measurements under the following subspecies), with the general coloration darker, in fresh plumage with a slight yellowish wash, absent in *dodsoni,* to the edges of the feathers of the mantle, this becoming more pronounced upon the rump and upper tail-coverts; edge of wing yellower than in *dodsoni;* feathers of lower breast more heavily striped centrally with dark brown; head blacker; nape appearing less distinctly striped because of the grayish white edging to the feathers.

Measurements of type (adult male).—Wing, 84 mm.; tail, 76; exposed culmen, 14.3; tarsus, 20.

Material.—Ten specimens from the Kapiti Plains region of British East Africa.

Remarks.—This form intergrades, both in size and coloration, with *Pycnonotus layardi micrus* in the Kapiti Plains region.

PYCNONOTUS LAYARDI PHÆOCEPHALUS, new subspecies

Brown-headed Bulbul

Type-specimen.—Adult female. Cat. No. 217202, U. S. N. M. Collected at Kikandwa (altitude about 3000 feet), Uganda, Africa, December 24, 1909, by Edgar A. Mearns. Original number, 17755.

Characters.—Intermediate between *Pycnonotus layardi fayi* and *P. l. minor* Heuglin. In extreme *minor,* from Gondokoro on the Bahr-el-Jebel, the head is scarcely darker than the mantle; in *fayi* the head is brownish black; in *phæocephalus* it is dark brown (between sepia and clove brown). The mantle, rump, upper tail-coverts, and flanks are decidedly more olivaceous than in *fayi* or *minor;* the abdomen is more buffy white; the crissum and under tail-coverts are a considerably deeper yellow (lemon yellow instead of canary yellow).

Measurements of type (adult female).—Wing, 92 mm.; tail, 82; exposed culmen, 15; tarsus, 21.5.

Remarks.—This peculiar form inhabits Uganda from Lake Victoria to Lake Albert. On the Upper Nile (Bahr-el-Jebel) this form rapidly passes into the subspecies *minor.*

COMPARATIVE MEASUREMENTS (IN MILLIMETERS) OF THE SUBSPECIES OF *PYCNONOTUS LAYARDI.*

Name.	Sex.	Number of Specimens.	Wing.	Tail.	Exposed Culmen.	Tarsus.
Pycnonotus layardi layardi	Male	5	99.0	89.8	17.3	22.9
Pycnonotus layardi micrus	Male	5	88.7	78.6	14.5	21.1
Pycnonotus layardi micrus	Female.	2	84.0	78.0	14.5	20.0
Pycnonotus layardi peasei	Male	4	84.3	75.8	14.5	20.1
Pycnonotus layardi peasei	Female.	4	77.8	72.5	13.7	19.5
Pycnonotus layardi dodsoni	Female.	1	81.0	78.0	14.0	19.0
Pycnonotus layardi fayi	Male	9	94.3	86.3	16.1	22.0
Pycnonotus layardi fayi	Female.	9	88.2	82.1	15.7	21.8
Pycnonotus layardi phæocephalus	Female.	1	92.0	82.0	15.0	21.5
Pycnonotus layardi minor	Male	9	91.7	83.0	15.2	20.9
Pycnonotus layardi minor	Female.	3	88.3	81.3	15.2	20.3

POGONOCICHLA CUCULLATA KENIENSIS, new subspecies

Mount Kenia Bush-Robin

Type-specimen.—Adult male. Cat. No. 215577, U. S. N. M. Collected at the altitude of 10,700 feet, on the west slope of Mount Kenia, British East Africa, September 29, 1909, by Edgar A. Mearns. Original number, 16942.

Characters.—Most closely related to the form from the Kilimanjaro region, German East Africa, to which Oberholser, in 1905, restricted Blyth's name *cucullata* (Ibis, 1867, p. 16), and which has also been known by the names *orientalis* (adult birds) and *guttifer* (young). The Mount Kenia bird is similar in size to *cucullata,* but

differs from it in its lighter coloration. The head and wings are a paler blue; the lores are dark blue; the mantle is a more golden olive-green; the rump-patch is a clearer yellow; the tail-feathers have more yellow on the bases of the feathers and correspondingly narrower black tips; the under parts are a clearer, less ochery yellow; the white brow-patch is larger.

A young male topotype, in first plumage (Cat. No. 215580, U. S. N. M.), is much paler than the young of *cucullata* from Mount Kilimanjaro, and has the pale centers of the feathers of the chest enlarged and grayish white, slightly tinged with yellow; the greater wing-coverts are not tipped with yellow; the chin, throat, and abdomen are grayish white, slightly mixed with blackish, and washed with pale buff; the yellow upon the inner webs of the rectrices extends nearly to their tips.

Measurements of type.—Wing, 83 mm.; tail, 68; culmen (chord), 13.5; tarsus, 25.

Remarks.—*Tarsiger elgonensis* Ogilvie-Grant, recently described from Mount Elgon, British East Africa, differs from *P. c. keniensis* in having the outer tail-feathers black except at the extreme base, which is yellow, and in being a trifle larger.

EMINIA LEPIDUS HYPOCHLORUS, new subspecies

Green-sided Bush-Warbler

Type-specimen.—Adult male. Cat. No. 215355, U. S N. M. Collected at Wambugu, 5500 feet, British East Africa, October 24, 1909, by Edgar A. Mearns Original number, 17301.

Characters.—Differs from *Eminia lepidus lepidus* Hartlaub, in being slightly larger and in the following details of coloration: the forehead is gray, almost as dark as the crown, instead of whitish; the olive-green of the upper parts is paler and yellower; the shoulder and bend of the wing have much less chestnut color; the under parts are gray instead of grayish white; the sides olive-green instead of gray faintly washed with green.

Measurements of type (adult male).—Wing, 66 mm.; tail, 69; culmen (chord), 18; tarsus, 26.

Comparative measurements.—Measurements of *Eminia lepidus lepidus* adult male: Wing, 67 mm.; tail, 65; culmen (chord), 16; tarsus, 26.

Average measurements of six adult males of Eminia lepidus hypochlorus: Wing, 69 mm.; tail, 70.5; culmen (chord), 17.9; tarsus, 26.1.

Average measurements of three adult females of Eminia lepidus hypochlorus: Wing, 66.7 mm.; tail, 62.3; culmen (chord), 17.2; tarsus, 24.7.

Remarks.—All of the specimens from west of Lake Victoria are typical *lepidus,* while those from British East Africa, east of Victoria Nyanza, are *hypochlorus,* although several specimens from the Southern N'Guaso Nyiro, in the Sotik District, and from Lake Naivasha verge toward the western form.

SYLVIETTA WHYTII LORINGI, new subspecies

Loring's Bush-Warbler

Type-specimen.—Adult male. Cat. No. 215360, U. S. N. M. Collected at Fort Hall, 3900 feet, British East Africa, October 28, 1909, by J. Alden Loring. Original number, 531.

Characters.—Most closely related to *Sylvietta whytii jacksoni,* but slightly smaller and considerably paler in color; the upper parts are more buffy, and paler, gray; the wing-quills are much paler brown; the under parts are pinkish buff instead of ochraceous-buff; the bill and feet lighter, with the mandible pale throughout.

Measurements of type (adult male).—Wing, 61 mm.; tail, 25; culmen (chord), 11.7; tarsus, 19.6.

Measurements of adult female topotype.—Wing, 56 mm.; tail, 25; culmen (chord), 11.5; tarsus, 18.

Average measurements of two adult males of Sylvietta whytii jacksoni.—Wing, 62.5 mm.; tail, 30; culmen (chord), 12; tarsus, 19.

Measurements of one adult female of Sylvietta whytii jacksoni.—Wing, 59 mm.; tail, 26; culmen (chord), 12; tarsus, 19.

Remarks.—I also refer to this form an adult female specimen (Cat. No. 118154, U. S. N. M.), collected at Taveta, British East Africa, July 6, 1888, by Dr. W. L. Abbott. It measures: Wing, 57 mm.; tail, 26; culmen (chord), 11; tarsus, 17. This specimen has been recorded as *Sylvietta whytii jacksoni* (Sharpe), by Oberholser, in the Proceedings of the United States National Museum, vol. xxviii, 1905, p. 906.

2

SMITHSONIAN MISCELLANEOUS COLLECTIONS

VOLUME 56, NUMBER 21

DESCRIPTION OF A NEW GENUS AND SPECIES OF HUMMING-BIRD FROM PANAMA

BY

E. W. NELSON

(PUBLICATION 2015)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
JULY 8, 1911

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

DESCRIPTION OF A NEW GENUS AND SPECIES OF HUMMINGBIRD FROM PANAMA

By E. W. NELSON

Since January, 1911, Mr. E. A. Goldman, of the Biological Survey, U. S. Department of Agriculture, has been detailed to the Smithsonian Biological Survey of the Panama Canal Zone to collect mammals and birds in the Canal Zone and adjacent parts of Panama. The most interesting discovery in his work to date has been a hummingbird representing a beautiful new genus and species. The type came from the higher slopes of the Cerro Azul, which rises to an altitude of 3200 feet about 15 miles northwest of Chepo, Panama. This high mountain lies at the extreme headwaters of the Chapres River, and Mr. Goldman writes that it is covered with forest which becomes smaller on the upper parts where these hummingbirds live.

I am indebted to Mr. Robert Ridgway, Curator of Birds in the U. S. National Museum, for directing my attention to the marked characters of this interesting hummingbird.

GOLDMANIA, new genus

Type *Goldmania* [illegible] new species. [illegible] named in honor of Mr. E. A. Goldman.

Generic characters.—[illegible] general appearance similar to *Lampornis* [illegible] *tea*, but under-tail [illegible] and [illegible] ones remarkably [illegible] strongly [illegible] shorter than [illegible] longer than [illegible] operculum [illegible] short, [illegible]

[illegible] new species

Type [illegible] Survey [illegible] 3200 [illegible] Cerro [illegible]

[illegible]

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

DESCRIPTION OF A NEW GENUS AND SPECIES OF HUMMINGBIRD FROM PANAMA

By E. W. NELSON

Since January, 1911, Mr. E. A. Goldman, of the Biological Survey, U. S. Department of Agriculture, has been detailed to the Smithsonian Biological Survey of the Panama Canal Zone to collect mammals and birds in the Canal Zone and adjacent parts of Panama. The most interesting discovery in his work to date has been a hummingbird representing a beautiful new genus and species. The type came from the higher slopes of the Cerro Azul, which rises to an altitude of 3200 feet about 15 miles northwest of Chepo, Panama. This high mountain lies at the extreme headwaters of the Chagres River, and Mr. Goldman writes that it is covered with forest which becomes smaller on the upper parts where these hummingbirds live.

I am indebted to Mr. Robert Ridgway, Curator of Birds, in the U. S. National Museum, for directing my attention to the marked characters of this interesting hummingbird.

GOLDMANIA, new genus

Type *Goldmania violiceps,* new species. Genus named in honor of Mr. E. A. Goldman.

Generic characters.—In general appearance similar to *Saucerottea,* but under-tail coverts small and very short; the three median ones remarkably specialized, being very narrow at base, broad and strongly decurved distally and very stiff; tenth, or outermost primary, shorter than ninth and abruptly attenuate near tip in adult male; bill longer than head, terete, narrow, slightly expanded basally and nasal operculum overlapping edge of mandible; feathers on tarsus very short, leaving inner side completely exposed.

GOLDMANIA VIOLICEPS, new species

Type No. 207754, adult male, U. S. National Museum, Biological Survey collection, from Cerro Azul, northwest of Chepo, Panama (3000 ft. altitude); collected by E. A. Goldman, March 23, 1911. (Original number 14173.)

Distribution.—Known only from 2500 to 3000 feet altitude on Cerro Azul, Panama.

Description of adult male (type).—Crown, forehead and lores dull iridescent violet; rest of upper parts from nape to upper tail coverts rich metallic green, becoming clearer or brighter posteriorly (closely similar to color of upper parts of neck and body in *Saucerottea cyaneifrons*); lower parts nearly uniform brilliant metallic green, brighter than back (similar to but brighter than in *cyaneifrons*); under tail coverts very short and shining green, except 3 middle ones, which are satiny white, stiff and recurved; wings uniform purplish black; tail feathers reddish chestnut, broadly margined, especially at tips, with bronze green; upper mandible blackish; lower mandible pale basally and shaded with dusky on terminal half.

Adult female (same date and locality as type).—Entire upper parts of head and body uniform, rather dull metallic green, becoming clearer posteriorly; under parts dull white mixed on sides of neck, breast and flanks with green feathers like those on back; under-tail coverts as in male; middle tail feathers mainly bronze green, with a very narrow dull rufous shaft streak on basal two thirds; other tail feathers dark rusty rufous along middle and margined by bronze green which occupies terminal fourth of the feathers; all but central pair of feathers with small central white spots at the tips; upper mandible dusky, lower one pale at base and becoming more dusky horn color on terminal two-thirds.

Immature male.—Upper parts plain green, nearly as in adult females, but rather brighter; under parts green mixed with grayish white on borders of feathers, especially on neck and breast, where the green in form of subterminal semilunar spots on median area give a scaled appearance; sides of neck and body and abdomen washed with duller metallic green; wings, tail and bill as in adult male, except broader bronze green tips to tail feathers and small terminal whitish spots at extreme tips, smaller than those in females.

Measurements.—Adult male (type), wing, 52.5 mm.; tail, 32.5 mm.; culmen, 19 mm. Adult female, wing, 47.5 mm.; tail, 25.5 mm.; culmen, 19 mm.

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 56, NUMBER 22

TWO NEW SUBSPECIES OF BIRDS FROM PANAMA

BY

E. W. NELSON

(PUBLICATION 2053)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
SEPTEMBER 7, 1911

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

TWO NEW SUBSPECIES OF BIRDS FROM PANAMA

By E. W. NELSON

While working on the Smithsonian Biological Survey of the Canal Zone,[1] Mr. E. A. Goldman of the Biological Survey, United States Department of Agriculture, collected specimens of two undescribed subspecies of birds which are characterized below.

HYLOMANES MOMOTULA OBSCURUS subsp. nov.

Panama Pigmy Motmot.

Type No. 229477, adult female, U. S. National Museum, Biological Survey Collection, from Cerro Brujo, Panama; collected by E. A. Goldman, June 7, 1911. (Original number 15049.)

Subspecific characters.—Size same as in typical *momotula*, but colors generally darker; the back and rump parrot green of Ridgway; outside of wings and top of tail olive green; breast and sides of neck and body darker, more olive, especially along flanks; bend of wing olive brownish and under wing coverts darker buffy.

PACHYSYLVIA OCHRACEICEPS BREVIPENNIS subsp. nov.

Panama Pachysylvia.

Type No. 229476, adult male, U. S. National Museum, Biological Survey Collection, from Lion Hill, Canal Zone; collected by E. A. Goldman, May 1, 1911. (Original number 14686.)

Subspecific characters.—Nearest *pallidipectus*, but with much shorter wings and tail; forehead and crown similarly tawny, but rest of upper parts of body from nape to upper tail coverts much more olive greenish; middle of back, scapulars and wing coverts dull olive brown, with much less russet than in either of the other forms; under parts of body from breast to under tail coverts pale, dingy, greenish yellow, with scarcely a trace of the ochraceous brown suffusion so marked in *ochraceiceps* and *pallidipectus*.

Measurements of type.—Wing, 53 mm.; tail, 40 mm.; tarsus, 17 mm.; culmen, 13 mm.

Remarks.—The great difference in length of wing and tail between the present form and the other subspecies, combined with the color differences, are almost sufficient to warrant giving this bird specific rank. One pair, shot on May 1, were the only specimens taken.

[1] This paper is the second dealing with the results of the Smithsonian Biological Survey of the Canal Zone.

SMITHSONIAN MISCELLANEOUS COLLECTIONS

VOLUME 56, NUMBER 23

ON PSOMIOCARPA, A NEGLECTED GENUS OF FERNS

WITH ONE PLATE

BY

DR. H. CHRIST, BASEL

(PUBLICATION 2054)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
NOVEMBER 21, 1911

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

ON PSOMIOCARPA, A NEGLECTED GENUS OF FERNS

By DR. H. CHRIST, Basel

With One Plate

The long discredited genus Psomiocarpa was established by C. B. Presl on one of the most extraordinary plants of the Philippine Islands, first discovered by the late Cuming and named by John Smith *Polybotrya apiifolia*. In conformity with our present views of generic relationship within the Polypodiaceæ this genus must now be reinstated, leaving out *Polybotrya acuminata* Link and *Polybotrya incisa* Link, which are true members of the genus Polybotrya, and including two American plants which are to be characterized in the present paper.

PSOMIOCARPA Presl, Epim. Bot. 161. 1849.

Genus a Polybotrya rhizomate brevi suberecto caespitoso nec aero-reptante, vernatione fasciculata nec eremobrya, et sporangiis segmenta fertilia undique tegentibus nec paginae inferiori solum affixis diversum. Folia sterilia plura fasciculato-rosulata, folium fertile solitarium, centrale.

1. PSOMIOCARPA APIIFOLIA Presl, l. c.

Polybotrya apiifolia J. Smith, Journ. Bot. 3: 401. 1841.

Foliis sterilibus subdeltoideis bipinnatis, versus basin postice auctis et tripinnatis, nervis lateralibus pinnularum furcatis. Folio fertili longe stipitato ideoque sterilia superante, lamina ad meras costas contracta, paniculiformi, segmentis remotis minutis globosis.

Planta pilis articulatis vestita.

Hab. Ins. Philippinae passim.

2. PSOMIOCARPA ASPIDIOIDES (Griseb.) Christ, Geograph. Farne 224. 1910.

Polybotrya aspidioides Griseb. Cat. Pl. Cub. 276. 1868.

Acrostichum aspidioides Baker, in Hook. & Baker, Syn. Fil. 414. 1868.

Foliis sterilibus late ovatis, basin versus non auctis nec angustatis, bipinnatifidis, pinnis ad alam angustam incisis, segmentis

sinu separatis obtusis, subintegris aut minute serrulatis, nervis lateralibus simplicibus. Folio fertili sterilia non superante, lamina contracta racemosa, segmentis elongatis brevissimis verruciformibus sessilibus confluentibus.

Planta squamis lanceolatis subulatisque vestita, sed fronde fertili fere glabra. Cellulis squamarum parietibus tenuissimis separatis.

Hab. Ins. Cuba, *Wright* 1827 (U. S. National Herbarium, no. 50575).

3. PSOMIOCARPA MAXONI Christ, sp. nov.

Psomiocarpa Maxoni Christ, Geograph. Farne 224. 1910 (*nomen nudum*).

Foliis sterilibus late ovatis basin versus non auctis nec angustatis, bipinnatifidis, pinnis ad alam angustam incisis, segmentis confertis

FIG. 1 — *Psomiocarpa Maxoni* Christ. Lowermost pinnae at natural size.

sive imbricatis, ovato-acutis, dentato-serratis, nervis lateralibus furcatis. Folio fertili sterilia longe superante, longissime stipitato, speciei praecedenti simili, sed racemo squamis subulatis creberrimis valde hispido.

Planta squamis lanceolatis vestita; cellulis squamarum parietibus incrassatis rufobrunneis tuberculatis separatis.

Hab. Ins. Jamaica, Holly Mount, Mount Diabolo, alt. 750 meters, *Maxon* 2228 (U. S. National Herbarium, no. 520143, type).

Remarks. — Psomiocarpa is so closely related to Dryopteris that one is tempted to consider its several species as aberrant Acrostichum-like forms of this genus, with condensed non-indusiate sori. On account of the shape of the sterile frond and of the scales, the two American species are more closely related to the *Lastrea pinnata* group of Dryopteris, while the only other species, from the Far East, with its compound frond and its hairs, comes nearer to the species of the *Lastrea decomposita* group, as, for instance, *D. dissecta* (Forst.).

The sporangia, which are smooth, globose, pedicellate, with thick rings of at least 20 articulations, as well as the ovate, brown spores, are perfectly alike in the three species.

As to the shape of the fertile segments, the distinction between "globose" and "elongate" is not absolute. For example, a single specimen of *Psomiocarpa apiifolia*, collected in 1895 at San Ramon, Mindanao, by Copeland (no. 1777), has a fertile frond the pinnules of which are not globose, but elongate and confluent, very much as in the American species.

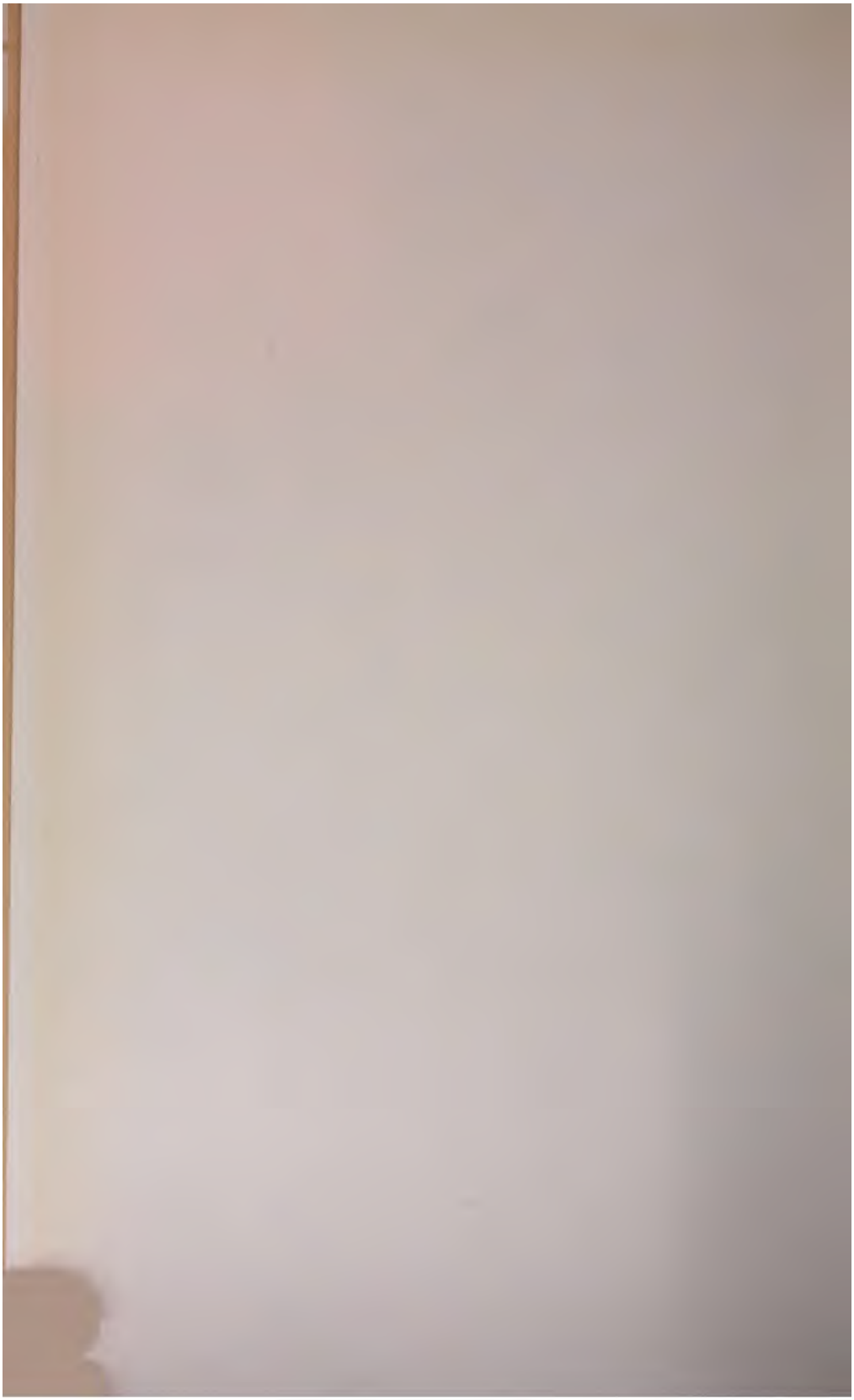
The presence of such a striking genus in Asia and America, although surprising, is not without parallel. One need cite only the case of Loxsoma of New Zealand and Loxsomopsis of Costa Rica.

The phylogenetic relations of Psomiocarpa tend toward Dryopteris and not Polybotrya. The latter seems to have rather more affinity to Polystichum, an intermediate form being *Polystichum apiifolium* C. Chr. (Dicksonia Sw.; syn. *Nephrodium duale* Donn.-Smith), which shows the trailing rhizome and the contracted fertile frond of Polybotrya, though it has also a reniform indusium.

EXPLANATION OF PLATE 1

Psomiocarpa Maxoni, at about two-fifths natural size. Type collection.

STANFORD LIBRARIES



SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 56, NUMBER 24

A REMARKABLE NEW FERN FROM PANAMA

With Three Plates

BY

WILLIAM R. MAXON

(Publication 2055)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
NOVEMBER 22, 1911

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

STANFORD LIBRARIES

POLYPODIUM PODOCARPUM Maxon

A REMARKABLE NEW FERN FROM PANAMA

By WILLIAM R. MAXON

(With Three Plates)

Toward the last of February, 1911, in the course of fieldwork connected with the Smithsonian Biological Survey of the Panama Canal Zone, I accompanied Mr. Henry Pittier from the Canal Zone, where our work had been carried on up to that time, to Chiriqui, the westernmost province of Panama, and spent nearly all of March in collecting plants—mainly ferns and lower cryptogams—in the mountains north of David, the principal city of the province. As indicating in a general way the character of this region, the following notes may be of value, inasmuch as other new ferns will be described later, in advance of a proposed paper dealing with the fern flora of Panama as a whole.

Our base of operations was the small town of El Boquete, which lies at an altitude of about 1,100 meters upon the immediate southern base of the extensive east-and-west range of mountains here forming the Continental Divide, and is reached from David by means of a rather indifferent ox-road of nearly 35 miles. The contrast between the gentle slopes of the open and nearly treeless wind-swept savannah region, through which the trail extends practically its whole length, and the territory from which the Rio Caldera issues abruptly at the foot of the mountains, is most pronounced. Ferns, which have been almost wholly wanting below, here become a conspicuous part of the vegetation. From El Boquete a few trails lead in various directions to the upper slopes of the heavily forested mountains and under tolerably good weather conditions afford fair opportunity for collecting. In less favorable weather, however, the term "rain forest" here acquires a new and truer significance; conditions of such intense and apparently perpetual humidity I have never seen in other parts of tropical America as here in the Cordillera of Chiriqui.

The most extended trips taken from El Boquete were one of four days to the summit of Chiriqui Volcano, which lies just south of the Cordillera and wholly in the dry zone; another to the twin peaks Cerro de la Horqueta, at the summit of the Cordillera; and a

third expedition (the most interesting of all to a collector of ferns) along a comparatively recent path, known from the name of the surveyor as "Holcomb's trail," which, though never wholly completed, was designed to cross the Divide to the northern (Atlantic) coast. It was upon this last trip that the peculiar species here to be described was collected. The first day's route lay wholly along the Rio Caldera, "Camp I" being some ten or twelve miles from El Boquete and in the midst of wet virgin forest at an altitude of about 1,625 meters. The second day's route proceeded through an even more humid forest above the Rio Caldera over a laboriously constructed trail, which is rapidly becoming obliterated, to the summit of the Divide at a point previously determined as about 1,925 meters above sea-level. "Camp II," which lies a short distance farther on and below, upon the Atlantic side, was not visited from lack of time. My collections for this day, which were very large, consisted entirely of material gathered between "Camp I" and the Divide. Among the many noteworthy pteridophyta collected, several of them new, none approaches in interest the species here to be described.

The first specimen of this peculiar species was secured at perhaps 1,750 meters elevation, on the trail referred to, above "Camp I," and from there all the way to the summit an occasional plant or tuft of plants would be found upon the smooth trunks of palms or other forest trees, usually at a distance of from two to six meters from the ground. The fact that the plant, though nowhere abundant, was sufficiently widespread to be encountered over an area of several miles, may safely be taken to indicate that the peculiar position of the sori, though apparently unique within the genus, is nevertheless normal for the species. The elongation of the pinnæ and their repeated division in a great majority of the fronds is discussed later, following the description. The species may be known as:

POLYPODIUM PODOCARPUM Maxon, new species

Plants epiphytic, the fronds pendent, usually numerous, closely fasciculate, 25 to 55 cm. long, subpinnate, the pinnæ sometimes simple, but mostly several to many times divaricately branched, both lamina and pinnæ of slow indeterminate growth. Rhizome prostrate or decumbent, rather slender and short, up to 4 cm. long, 4 to 6 mm. in diameter, the older portion clothed with the imbricated bases of numerous dead fronds, the crown bearing a few nearly concealed lanceolate, plicate, cucullate or subtubulose, entire, bright brown scales 3 to 5 mm. long; stipes stoutish, greenish from a dull

brown base, or discolored throughout, 1 to 6 cm. long or nearly wanting, flattened, very narrowly alate above (gradually passing into the narrowly winged rachis), rather densely pilose with very slender, fragile, spreading, rufous hairs 2 to 3.5 mm. long; lamina 20 to 50 cm. long, of varying form and indeterminate growth, readily abortive at the apex, the pinnæ simple and usually elongate, or greatly extended and freely branched near or beyond their middle, the numerous slender branches commonly forming a subdichotomy; pinnæ spreading or slightly ascending, adnate, joined uniformly by a narrow wing about 1 mm. broad, decurrent, the simple ones linear-caudate, 4 to 14 cm. long, 3 to 5 mm. broad and entire if sterile, if fertile distantly and obliquely serrate-pectinate to dentate, 5 to 9 mm. broad including the teeth or lobes, these 1 to 3 mm. long, rounded and soriferous at the apex; veins free, very oblique, the sterile ones 1- to 3-forked, the fertile ones forked, the sorus borne at the clavate apex of the greatly elongated anterior branch, very close to the margin; sori large, hemispherical, or by their position nearly globose, the sporangia arising from the lower surface but crowding outward in the plane of the lamina, the sorus thus appearing nearly or quite terminal upon the lobe; leaf tissue of young plants firmly membrano-herbaceous, the veins apparent by transmitted light, of mature plants thicker and spongiose, the veins seen with difficulty; both surfaces of the lamina (including the greenish rachis and nearly concealed midveins) covered throughout with short, distant, dark, gland-like hairs.

Type in the U. S. National Herbarium, no. 676092, collected from a tree trunk in the humid forest of the upper Caldera water shed, between "Camp I" and the Divide, Holcomb's trail, above El Boquete, province of Chiriqui, Panama, altitude 1,750 to 1,925 meters, March 23, 1911, by William R. Maxon (no. 5640).

The specimen designated as the type is but one of several mounted plants (numbers 5640 and 5656) showing the extremes of leaf form within the species. It is shown at exactly one-half natural size in Plate 1 and may be taken to indicate the "normal" form of the mature frond. Plate 2 represents at the same scale a plant of no. 5656 in which the tendency toward repeated dichotomy of the pinnæ has found ample expression. Plate 3, at about two-fifths natural size, shows a plant of no. 5640 approaching maturity and possessing an unusually large number of fronds, most of which have escaped injury at the apex while young and have in consequence attained a fair length.

A reasonable explanation of the remarkable leaf form developed by many individual fronds is, I believe, found in the following hypothesis, which has been substantiated by a careful examination of the series of specimens. It is that, notwithstanding the indeterminate growth of the lamina and of the pinnæ at their apices, the fronds would, if fully protected from injury by natural causes (such as injury by wind or by the falling of water-filled parasites from the heavily laden branches above), develop in a nearly symmetrical form. (See Plate 1, in which the frond had apparently attained a fair size before the apical portion was lost. There is no abortive tip; the whole apical portion has been broken off.) Plate 2 would appear to controvert this supposition somewhat; but an examination of the specimen itself shows the apex of this frond to be dead and discolored, and the other five or six fronds to have been broken off short and to have "forced" the activities of the entire plant to seek an outlet through a single channel, namely, the further development of the pinnæ of the one remaining frond, each (if uninjured) with its nearly dormant or slowly unrolling minute terminal bud. The alternative would have been the development or pushing out of new fronds, a feature which is, possibly, seasonal.

Further evidence is offered by a great number of mutilated fronds, and in particular (among the mounted specimens) by one not here figured (U. S. Nat. Herbarium, no. 676090) which has the stipe short and stout, the rachis 7 cm. long, the lamina there broken off sharply by natural injury and wanting, the pinnæ missing on one side of the basal remnant, and those on the other side several times dichotomous and produced to a length of 18 cm. A frond of another plant has several pinnæ similarly developed to a length of from 18 to 24 cm.

Instances of indeterminate growth in Polyopodium are, I think, not very common, but the following readily occur: (1) That of *P. jamesonioides* Fée[1], a species described from Colombia (*Schlim* 399), recently collected by me on Chiriqui Volcano at an altitude of about 3,000 meters (no. 5340), in which the slender simply pinnate fronds are obviously of indefinite evolution, the apex being invariably terminated by a crosier-like nascent bud; (2) that of *P. heteromorphum* Hook. and Grev., which with its dichotomous fronds is well known in several forms; (3) and that of the West Indian *P. curvatum* Sw. (of which *P. inaequale* Fée[2] is an exact

[1] Fée, 7me Mém. Foug. 59. *pl. 21. f. 4.* 1857.
[2] Fée, 11me Mém. Foug. 47. *pl. 12. f. 3.* 1866.

synonym), in which a close examination shows the apices of perfect fronds to be not truly determinate, but rather, as in *P. podocarpum*, to remain in a nascent state long after the older parts of the frond have reached maturity.

As to the cause of the development of the dichotomous form of the pinnæ in fronds of *P. podocarpum*, in preference to the simple elongation of its pinnæ by the same method of indefinite evolution, no especial explanation need be sought, inasmuch as instances of repeated subdivision of apical growth in ferns are exceedingly common. But it may be mentioned that in the whole series of this species not one of the fronds is subdivided at its apex, and in only one is the rachis forked, the simple division in this instance having been caused by an injury. The repeated subdivision of the fronds occurs invariably in the pinnæ. This is only partially accounted for by the greater likelihood of injury to the apex of the frond.

With respect to relationship, *Polypodium podocarpum* is clearly allied to *P. curvatum*, its nearest relatives being perhaps the Andine species *P. pilipes* Hook.[1] and *P. pozuzoense* Baker,[2] the former from Peru, the latter from Ecuador. But these are species with deeply pectinate-pinnatifid pinnæ, and the former, at least, has simple veins. Both differ from *P. podocarpum* very conspicuously in the position of their sori, which are not placed apically upon special teeth or lobes. The position of the sori in *P. podocarpum*, indeed, demands especial notice, for it is not only apparently new for the genus Polypodium (Eupolypodium), but seems to reverse the usual observed fact that fertility is commonly accompanied by a loss of foliar tissue. The contrary is here true; the pinnæ are entire where sterile, and toothed or lobed only where soriferous; there are no sterile lobes on the fertile fronds. Moreover, the apical position of the sori is so pronounced a feature as to suggest strongly the recognition of this species as a distinct generic type. Without a more critical study of its closest allies this hardly appears desirable; but it is difficult to escape the conviction that, as proven similarly by Mr. Christensen in the case of Dryopteris, the genus Polypodium (restricted to Eupolypodium) is susceptible of division into several well-defined sections, which will be more than "groups of closely related species," in that they may be recognized by definite characters afforded by a study of their minute morphology and their method of growth.

---

[1] Hook. Ic. Pl. *pl. 221.* 1840.

[2] Hook. Ic. Pl. *pl. 1672.* 1886.

POLYPODIUM PODOCARPUM Maxon

Digitized by Google

POLYPODIUM PODOCARPUM Maxon

SMITHSONIAN MISCELLANEOUS COLLECTIONS

VOLUME 56, NUMBER 25

DESCRIPTIONS OF SEVEN NEW AFRICAN GRASS-WARBLERS OF THE GENUS CISTICOLA

BY

EDGAR A. MEARNS

Associate in Zoology, U. S. National Museum

(PUBLICATION 2056)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
NOVEMBER 23, 1911

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

DESCRIPTIONS OF SEVEN NEW AFRICAN GRASS-WARBLERS OF THE GENUS CISTICOLA

By EDGAR A. MEARNS

ASSOCIATE IN ZOOLOGY, UNITED STATES NATIONAL MUSEUM

This paper is the fifteenth dealing with the results of the Smithsonian African Expedition, under the direction of Col. Theodore Roosevelt. It embraces descriptions of seven new species and subspecies of birds, four of which were discovered by members of the expedition.

All of the measurements submitted in this paper are in millimeters; and the designation of colors conforms to Mr. Robert Ridgway's "Nomenclature of Colors," 1886.

CISTICOLA PRINIOIDES KILIMENSIS, new subspecies

Mount Kilimanjaro Grass-Warbler

Cisticola prinioides OBERHOLSER, Proc. U. S. Nat. Mus., Vol. 28, 1905, p. 902 ("Six specimens, from Mount Kilimanjaro, at 5,000, 6,000, and 8,000 feet, April 3 to 11, 1888.")—SJÖSTEDT, Wiss. Ergeb. Schwed. Zool. Exped. Kilimandjaro, III, Vögel, 1908, p. 149 (Kilimanjaro).

Type-specimen.—Adult male. Cat. No. 118025, U. S. N. M. Collected at Maranu, altitude of 5,000 feet, on Mount Kilimanjaro, German East Africa, April 3, 1888, by Dr. W. L. Abbott.

Characters.—Most closely related to *Cisticola prinioides prinioides* Neumann, from Mau, British East Africa, but differs in having the upper parts less uniformly colored, and the under parts darker, without a well-defined whitish area along the middle of the abdomen. The russet crown is more distinctly spotted with dark centers to the feathers. The mantle is grayer, with blacker centers to the feathers.

Measurements of type (adult male).—Length (of skin), 147; wing, 58; tail, 69; culmen, 13; tarsus, 24.

Material.—Six specimens, collected by Dr. W. L. Abbott, on Mount Kilimanjaro, at the altitudes of 5,000, 6,000, and 8,000 feet.

Remarks.—This form may be distinguished from *Cisticola prinioides neumanni* (Hartert), from Mount Kenia, British East Africa, by its paler, more grayish, and more spotted upper parts; and the

under surfaces are browner, less grayish, in *kilimensis* than in *neumanni*.

CISTICOLA SUBRUFICAPILLA ÆQUATORIALIS, new subspecies

Equatorial Grass-Warbler

Type-specimen.—Adult male. Cat. No. 214431, U. S. N. M. Collected at Lake Naivasha, altitude 6,350 feet, British East Africa, July 22, 1909, by Edgar A. Mearns. Original number, 16355.

Characters.—Much larger than *Cisticola subruficapilla subruficapilla* (A. Smith); coloration darker; median stripes on feathers of upper parts broader and blacker; tail and outer aspect of wings less rufescent.

Description.—Pileum and cervix pale sepia, the feathers centrally striped with blackish brown; lores white or (sometimes) rusty white; no light stripe above eye; ear-coverts grayish brown; back, rump, and upper tail-coverts dark hair brown, the feathers of the mantle with conspicuous brownish-black centers; wings externally dark brown, with outer webs edged with dull cinnamon; tail above dark reddish brown, obscurely fasciated, all but the central pair of rectrices subterminally banded with black and tipped with pale drab; chin and upper throat white; middle of chest and abdomen white, washed with cream-buff; sides brownish gray washed with buff; thighs clay color; axillars and bend of wing creamy white; under wing-coverts and inner border of quills pinkish buff; crissum cream-buff; under surface of tail pale drab (sometimes rusty), the feathers subterminally crossed by a complete black band about five millimeters in width. Iris yellowish brown; bill blackish brown above and flesh color below; feet and claws light brown.

Measurements of type (adult male).—Length (of skin), 140; wing, 61; tail, 58; exposed culmen (chord), 13.5; tarsus, 24.

Average measurements of eight adult males.—Wing, 66.1; tail, 58.3; culmen (chord), 13.4; tarsus, 24.5.

Average measurements of four adult females.—Wing, 57; tail, 49.3; culmen (chord), 12.3; tarsus, 23.6.

Measurements of one adult male topotype of Cisticola subruficapilla subruficapilla.—Wing, 52; tail, 50; culmen (chord), 11.2; tarsus, 20.

Material.—Twelve adults from Juja Farm (Athi River), Heatley's Farm (Kamiti), Southern N'Guaso Nyiro River (Sotik District), Oljoro-o-Nyon River, Lake Naivasha, Gilgil, Laikipia, and Guaso Nyiro River, all in British East Africa.

CISTICOLA SUBRUFICAPILLA BOREA, new subspecies

Northern Grass-Warbler

Type-specimen.—Adult male. Cat. No. 217127, U. S. N. M. Collected at "Rhino Camp,"[1] on the Bahr el Jebel, Lado Enclave, Africa, January 30, 1910, by Edgar A. Mearns. Original number 18244.

Characters.—Similar to *Cisticola subruficapilla æquatorialis* Mearns, but smaller and much paler in coloration.

Description.—Pileum and cervix pale bistre, the feathers centrally striped with dark brown; lores white; ear-coverts and sides of neck drab; back, rump, and upper tail-coverts light hair brown, the feathers of the mantle with dark brown centers; wings dark brown, with fulvous edging to the outer webs of the primaries, and drab edging to the outer webs of the secondaries and wing-coverts; tail broccoli brown, obscurely fasciated, all but the central pair of feathers crossed by a subterminal black band and narrowly tipped with écru drab; chin, throat, and middle of abdomen white; sides pale grayish drab washed with cream-buff; thighs pale brownish gray; axillars and lining of wings creamy white; under wing-coverts and inner border of quills pale pinkish buff; under tail-coverts soiled white; under surface of tail écru drab, the feathers subterminally crossed by a complete black band about four millimeters in width. Bill (in dry skin) dark brown above and flesh color below; feet and claws light brown.

Measurements of type (adult male.)—Length (of skin), 132; wing, 62; tail, 54; culmen (chord), 13.5; tarsus, 25.5.

Measurements of adult male (Cat. No. 217129, Bahr el Jebel at Gondokoro, Uganda, February 25, 1910).—Wing, 64; tail, 58; culmen (chord), 13; tarsus, 25.

CISTICOLA ALLENI, new species

Allen's Grass-Warbler

Type-specimen.—Adult male. Cat. No. 56127, Museum of Comparative Zoology, Cambridge, Massachusetts. Collected on the Meru River, British East Africa, August 12, 1909, by Dr. Glover M. Allen.

Characters.—This species appears to be most closely related to the *Cisticola subruficapilla* group, from which it differs in the relatively stouter, more curved bill, pallid grayish coloration, cinereous outer aspect of the primaries, and white tips to the tail-feathers.

[1] "Rhino Camp" is on the left (west) bank of the Nile ("Bahr el Jebel"), about 15 miles north of Wadelai, latitude 2° 55′ north.

Description.—Upper parts brownish gray, slightly rufescent on the crown; feathers of mantle and crown centrally striped with dark brown; wing-coverts and quill-feathers dark brown with broad hoary edging; feathers of rump and upper tail-coverts cinereous, with obsolete median dark streaks; rectrices dusky brownish gray, obscurely fasciated, all but the central pair with a broad subterminal band of black and pure white tip; lores and sides of face, below eye, white; ear-coverts pale grayish brown; under parts white with a faint tinge of buff across chest and along sides; edge of wing white; under wing-coverts creamy white; inner border of quill-feathers buffy white; under surface of rectrices gray, all but the middle pair crossed by a subterminal black bar seven millimeters in width and broadly tipped with pure white. Bill, in dry specimens, pale brown above, flesh color on mandible and sides of maxilla; feet and claws light brown.

Measurements of type (adult male).—Length (of skin), 115; wing, 63; tail, 57; culmen (chord), 13; tarsus, 23.

Measurements of adult male topotype.—Length, 115; wing, 67; tail, 55; culmen (chord), 12; tarsus, 24.

Material.—Two adult males, collected by Dr. Glover M. Allen, on the Meru and Guaso Nyiro Rivers, north of Mount Kenia, in British East Africa.

CISTICOLA STRANGEI KAPITENSIS, new subspecies

Kapiti Plains Grass-Warbler

Type-specimen.—Adult male. Cat. No. 213547, U. S. N. M. Collected at Potha, altitude 4250 feet, Kapiti Plains, British East Africa, April 29, 1909, by Edgar A. Mearns. Original number, 15644.

Characters.—Most closely related to *Cisticola strangei pachyrhyncha* (Heuglin),[1] from the "forest-region of Bongo, in Central Africa," from which it differs in being much paler and more grayish. *Cisticola argentea* Reichenow,[2] which is apparently a subspecies of *Cisticola strangei* (Fraser),[3] is larger, grayer, and with more grayish sides than the present form. The salient differences in three closely related forms of *Cisticola strangei* may be stated as follows:

---

[1] Ibis, 1869, pp. 130 and 131, in text (new name for *valida* Peters).

[2] Ornith. Monatsb., Vol. 13, 1905, p. 25.

[3] *Drymoica strangei* L. Fraser, Proc. Zool. Soc. Lond., Pt. 11, No. 121, July, 1843, p. 16.

Cisticola strangei strangei	*Cisticola strangei pachyrhyncha*	*Cisticola strangei kapitensis*
Pileum prout's brown, the feathers inconspicuously edged with wood brown.	Pileum bistre, without conspicuous edging to the feathers.	Pileum pale brown, the feathers broadly edged with pale grayish clay color.
Nape similar to crown.	Nape similar to crown.	Nape pale clay color, with darker centers to the feathers, contrasting with color of crown and mantle.
Mantle dark brown, the feather edging paler, more yellowish brown.	Mantle darker brown, the feather edging not in strong contrast with the dark centers.	Mantle paler, with broad grayish margins strongly contrasting with the dark centers to the feathers.
Outer surface of wing-quills russet.	Outer surface of wing-quills wood brown.	Outer surface of wing-quills wood brown.
Under surfaces deep yellowish olive-buff.	Under surfaces pale yellowish olive-buff.	Under surfaces buffy white.

Measurements of type (adult male).—Length (of skin), 128; wing, 68; tail, 51; exposed culmen (chord), 13.1; tarsus, 29.

Comparative measurements of adult males:

	Wing	Tail	Exposed culmen	Tarsus
Cisticola strangei strangei	69.0	53.0	13.0	29.0
Cisticola strangei pachyrhyncha	69.0	50.0	13.0	29.0
Cisticola strangei kapitensis	67.6	51.0	13.1	28.5

Material.—Five adult males from British East Africa.

Remarks.—I noted the color of the iris of the type specimen as "pale brownish yellow." On two specimen labels, Mr. G. L. Harrison, Jr., has noted: "Iris light brown; bill dusky; legs and feet flesh color."

CISTICOLA DIFFICILIS, new species

Lakiondu Grass-Warbler

Type-specimen.—Adult female. Cat. No. 56129, Museum of Comparative Zoology. Collected at Lakiondu, north of Mount Kenia, British East Africa, September 7, 1909, by Dr. Glover M. Allen.

Characters.—Similar to *Cisticola sylvia* Reichenow, but striped above and slightly smaller. In general coloration it is not very unlike *Cisticola emini* Reichenow, though striped and more yellowish above and more strongly fulvous below.

Description.—Pileum and cervix plain sepia brown; mantle sepia, the feathers mesially striped with blackish brown; rump and upper tail-coverts rather pale yellowish brown; wings bistre, washed with cinnamon on the outer webs of quills; tail above bistre, showing

faint cross-bars, subterminally banded on all of the feathers with obsolete dusky bars which are black on the under surface, and tipped with grayish drab; lores and supraorbital stripe soiled white; sides of head pale grayish brown; under parts pale grayish brown, whitish on throat and middle of abdomen; thighs broccoli brown; edge of wing white; under wing-coverts buff-yellow; inner webs of quills buffy gray; under side of tail grayish drab, subterminally banded with black (these bands about six millimeters in width on outer rectrices), and broadly tipped with yellowish drab. In the dry skin the ridge of the maxilla is brown, the mandible and sides of maxilla flesh color; feet and claws pale yellowish brown.

Measurements of type (and only specimen).—Length (of skin), 120; wing, 54; tail, 52; culmen (chord), 12.5; tarsus, 21; width of middle tail-feather, 10.

CISTICOLA HYPOXANTHA REICHENOWI, new subspecies

Reichenow's Grass-Warbler

Cisticola hypoxantha OBERHOLSER, Proc. U. S. Nat. Mus., Vol. 30, 1906, p. 805.

Type-specimen.—Adult male. Cat. No. 215430, U. S. N. M. Collected at Changamwe (sea-level), British East Africa, November 30, 1909, by Edgar A. Mearns. Original number, 17702.

Characters.—Similar to *Cisticola hypoxantha hypoxantha* Hartlaub from the upper Nile Valley, but paler, and less distinctly streaked above.[1]

Measurements of type (adult male).—Length (of skin), 100; wing, 48; tail, 37; exposed culmen (chord), 10.3; tarsus, 20.

Material.—Eight specimens of the present form from Mombasa and Changamwe, on the coast of British East Africa; five specimens of *Cisticola hypoxantha hypoxantha* Hartlaub from near the type locality (Lake Albert).

Remarks.—Dr. Reichenow, to whom the specimens collected by William Doherty at Mombasa were submitted, considered this form distinct; but in the absence of specimens from the type locality of *Cisticola hypoxantha,* Mr. Oberholser was unwilling to name the Mombasa bird, which I now take pleasure in naming for Dr. Anton Reichenow.

[1] For a detailed description of this form see Oberholser, Proc. U. S. Nat. Mus., Vol. 30, June 4, 1906, p. 806.

SMITHSONIAN MISCELLANEOUS COLLECTIONS

VOLUME 56, NUMBER 26

FOUR NEW MAMMALS FROM THE CANADIAN ROCKIES

BY

N. HOLLISTER

(PUBLICATION 2062)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
DECEMBER 5, 1911

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

FOUR NEW MAMMALS FROM THE CANADIAN ROCKIES

By N. HOLLISTER

A small party from the Smithsonian Institution accompanied the Alpine Club of Canada expedition to Jasper Park and the Mount Robson region, during the summer of 1911. Among the mammals collected are specimens of a new chipmunk, a new mantled ground-squirrel and two new bats.[1]

EUTAMIAS LUDIBUNDUS, sp. nov.

Type from Yellowhead Lake,[2] British Columbia; 3700 feet. Cat. No. 174225, U. S. National Museum; skin and skull, female adult. Collected August 29, 1911. N. Hollister; original No. 3987.

General characters.—A large member of the *amœnus* group, nearest related to *Eutamias luteiventris,* but with sides of quite a different tint; darker and more tawny, less bright and yellowish. Underparts without the yellowish color of *luteiventris;* tail darker beneath.

Color of type (post-breeding pelage).—Top of head, rump, and upper surface of hind legs to heel, grizzled hair-brown. Five dark stripes on back nearly pure black; the two inner light stripes grayish; outer light stripes creamy-white, mixed with gray. Cheeks, sides, shoulders, and fore legs, dark cinnamon; feet wood brown. Ears blackish outside, brown inside; a white area at base extends to tip of ear in a broad band. Underparts whitish, without yellowish tint, but with a faint suffusion of cinnamon-tawny on sides of middle of belly. Tail above mixed black and dark buff; below with central area russet, bordered by bands of black and tawny-olive.

Skull.—Like skull of *Eutamias luteiventris,* but averaging slightly larger.

Measurements of type.—Head and body, 126 mm.; tail vertebræ, 96; hind foot, 34. Skull: Greatest length, 33.7; condylobasal length, 31; zygomatic breadth, 19.6; upper tooth row, 5.5.

---

[1] Some new species of birds collected by this expedition are described by J. H. Riley in Proc. Biol. Soc. Washington, Vol. 24, pp. 233-236, 1911.

[2] This is the Cowdung Lake of many maps. It lies about six miles west of the Alberta-British Columbia line, in Yellowhead Pass.

Remarks.—This chipmunk is not closely related to either *Eutamias affinis* or *E. borealis,* but is apparently a northern form of *luteiventris.* It bears some resemblance to *Eutamias felix,* but is readily distinguished from that species by its much less reddish coloration. The close similarity between the skulls of *felix, ludibundus,* and *luteiventris,* and the general type of coloration exhibited by all three, make it seem possible that series of specimens collected between the known ranges will show intergradation between these forms. At present the material does not warrant treating them as subspecies. From *E. borealis,* with which it does not intergrade, in this region at least, *ludibundus* may be easily separated by its large size, large foot, reddish, not gray, tail, and larger skull. Specimens of *E. borealis* were collected by our party at Prairie Creek, and at Brule Lake, Alberta. West of these points, at Henry House, Alberta, and along the British Columbia boundary line, all the chipmunks collected are of this new form. From *E. affinis,* this form differs conspicuously in the general color of the back and rump, showing far less clear white, and with rump, legs, and inner light stripes much darker brownish-gray; cheeks, shoulders, and sides very much darker. I am under obligations to Mr. Arthur H. Howell for pertinent criticism and assistance during my work in this most difficult genus.

A large series of specimens of this new chipmunk was collected, all from the region along the boundary line between British Columbia and Alberta, from Yellowhead Pass northward.

CALLOSPERMOPHILUS LATERALIS TESCORUM, subsp. nov.

Type from head of Moose Pass branch of the Smoky River, Alberta (near Moose Pass, B. C.), at 7000 feet. Cat. No. 174165, U. S. National Museum; skin and skull, male adult. Collected August 2, 1911. N. Hollister; original No. 3863.

General characters.—Nearest to *Callospermophilus lateralis cinerascens,* but larger, darker, and richer colored; mantle darker and extending further back over shoulders; under side of tail clear cinnamon color with black subterminal border to hairs (in *cinerascens* the under side of the tail is mixed pale buff and black); upper side of tail with less black.

Color of type.—Nose, top and sides of head, neck and shoulders, glossy Mars brown; ring around eyes, whitish; back grizzled brownish-gray, darkening on rump. Lateral stripes sharp and distinct, the dark ones clear black from shoulders to middle of body, the posterior half colored like back; inner black stripes short, reaching only little

past the middle of body. Shoulders and upper part of fore legs suffused with blackish. Hind legs dark brown outside to heel. Tail above black and buff mixed; below with central area clear cinnamon, border black and cinnamon-buff. Sides and underparts of body buffy-white, strongly suffused with darker buff.

Skull and teeth.—Skull averaging larger than that of *C. l. cinerascens,* with slightly larger teeth.

Measurements.—Type: Head and body, 198 mm.; tail vertebræ, 105; hind foot, 45. Average of nineteen specimens from type region compared with average of fifteen specimens of *cinerascens* from Montana, the latter in parentheses: Head and body, 194 (178); tail vertebræ, 104 (95); hind foot, 43 (40.9). Skull of type: Greatest length, 47; condylobasal length, 44; zygomatic breadth, 29.4; nasals, 15.5; upper tooth row, 9.0.

Remarks.—Twenty-seven specimens of this new form were collected, twelve at the type locality, and fifteen at nearby points across the line in British Columbia.

MYOTIS ALTIFRONS, sp. nov.

Type from Henry House, Alberta, at 3350 ft. altitude. Cat. No. 174133, U. S. National Museum; skin and skull, adult male (teeth considerably worn). Collected September 5, 1911. J. H. Riley; original No. 2317.

General characters.—About the size of *Myotis lucifugus,* but differing widely in color and cranial characters. Upperparts very dark brown; forearm shorter than in *M. lucifugus longicrus,* longer than in *M. yumanensis saturatus;* border of interfemoral membrane without trace of fringe; wing from base of toes; tragus long and narrow. Skull with unusually inflated braincase, giving the effect of a turned up nose much as in *M. capitaneus* from Lower California.

Color of type.—Upperparts very dark brown; the underfur dull black, and hair tips brown; a thin border of clear burnt umber hairs between hips, around base of interfemoral membrane. Underparts dark drab-brown. Ears and membranes blackish.

Skull and teeth.—Skull about the size of skulls of *M. l. longicrus;* facial concavity greater; braincase higher, the inflation of the anterior portion making it appear very much larger, compared with rostrum, than in *lucifugus* or any of its forms. The teeth in the type specimen are much worn, but appear to be essentially as in *longicrus.*

Measurements of type.—Head and body, 49 mm.; tail vertebræ, 39.5; hind foot, 9.5 (measured in flesh by collector); forearm, 36.5;

tibia, 17; ear from notch, 13; tragus from notch, 6.7 (from dry skin). Skull: Condylobasal length, 13.7; breadth of braincase, 8.0; interorbital breadth, 4.4; upper tooth row, including canine, 5.4.

Remarks.—This bat is immediately distinguishable from any species known from the United States and Canada by the peculiar high and inflated braincase and apparent shortness of the rostrum. The color is even slightly darker than the darkest skins of *M. l. alascensis* and *M. y. saturatus* that I have seen. It is slightly larger than *M. keenii,* with smaller ear and tragus. The species is based upon a single specimen.

MYOTIS PERNOX, sp. nov.

Type from Henry House, Alberta. Cat. No. 174134, U. S. National Museum; skin and skull, adult male. Collected September 6, 1911. J. H. Riley; original No. 2318.

General characters.—A dark brown *Myotis,* externally resembling *M. lucifugus lucifugus,* but with larger foot. Interfemoral membrane edged with scattering hairs. Skull differs from that of *lucifugus* in its larger size and more depressed braincase.

Color of type.—Upperparts uniform glossy brown, nearest to the bistre of Ridgway; underparts dark Isabella color; ears and membranes blackish.

Skull and teeth.—The skull is essentially like that of *M. lucifugus lucifugus,* except that the size is greater, and the braincase is much flattened. The ventral surface, including the teeth, presents much the same appearance, except for size, as does that of *lucifugus.*

Measurements.—Type and topotype, the latter in parentheses: Head and body, 53 mm. (54); tail vertebræ, 39 (44); hind foot, 11 (12), measured in flesh by collector. Forearm, 37.7 (38.6); tibia, 16.7 (17); ear from notch, 12.5 (12.2); tragus from notch, 7.6 (8.0), from dry skin. Skull: Condylobasal length, 14.8 (14.9); breadth of braincase, 8.0 (8.0); interorbital breadth, 4.1 (4.2); upper tooth row, including canine, 5.5 (5.7).

Remarks.—This bat might, from external examination, be readily mistaken for *M. lucifugus lucifugus,* but the characters of the skull will at once distinguish it. The black ears and membranes also serve to separate it; *M. l. lucifugus* has brown wings and interfemoral membrane. Two specimens of this species, both males, were collected the same evening.

SMITHSONIAN MISCELLANEOUS COLLECTIONS

VOLUME 56, NUMBER 27

A NEW KINGFISHER FROM PANAMA

BY

E. A. GOLDMAN

(PUBLICATION 2058)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
DECEMBER 1, 1911

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

A NEW KINGFISHER FROM PANAMA

By E. A. GOLDMAN

Among the birds obtained in the course of the Smithsonian Biological Survey of Panama[1] are 28 kingfishers of the *Ceryle americana* group. Comparison of this large series, and examination of the birds from numerous localities in northern South America and within the wide distribution area (Panama to southern United States) originally assigned to *Ceryle septentrionalis* Sharpe, show that two well-marked races have been united under this name. One of these ranges northward through Panama, Costa Rica, Nicaragua, and Honduras to Guatemala, passing thence into the form which reaches the southern border of the United States.

When *Ceryle septentrionalis* Sharpe was originally described no type specimen or type locality was mentioned, but Mr. C. Chubb, of the British Museum, has very kindly written me, under date of October 13, 1911, the following: "In reply to yours respecting *Ceryle septentrionalis* Sharpe, I have much pleasure in saying that the types of the original descriptions of the male and female were collected at Teapa, Mexico, in March, no year or day of month given, by D. W. S., who is the wife of H. H. Smith; these form a part of the Salvin-Godman Collection." Teapa, Tabasco, Mexico, must therefore be accepted as the type locality of *C. a. septentrionalis*. Fortunately this locality is within the geographic range of the most northern form of the group, so that the name is well applied.

This disposal of *C. a. septentrionalis* leaves the hitherto unseparated form of the southern part of Middle America without a name. It may be characterized as follows:

CERYLE AMERICANA ISTHMICA, new subspecies

Type from Rio Indio (near Gatun), Canal Zone, Panama. No. 207628, male adult, U. S. National Museum (Biological Survey collection), collected by E. A. Goldman, February 23, 1911. Original number, 13820.

[1] This paper is the fourth dealing with the results of the Smithsonian Biological Survey of the Panama Canal Zone.

Characters.—Similar to *C. americana americana*, but larger, with stouter bill; greenish-black submalar stripe narrower; chestnut-rufous pectoral area of male less extended anteriorly (encroached upon by white of throat); greenish-black pectoral bands of female narrower, more interrupted. Similar to *C. americana septentrionalis*, but smaller; wings more narrowly banded with white; pileum much less distinctly flecked with white anteriorly; male with under parts more heavily spotted with greenish-black, the chestnut-rufous pectoral area more extended anteriorly (less encroached upon by white of throat); female with broader pectoral bands.

Measurements.—Type: Wing, 79.5 mm.; tail, 55.6; culmen, 45.5; depth of bill at anterior angle of nostril, 9.5; width of bill at anterior angle of nostril, 6.7; tarsus, 8.7.

SMITHSONIAN MISCELLANEOUS COLLECTIONS

VOLUME 56, NUMBER 28

DESCRIPTION OF A NEW SPECIES OF SUN-BIRD, HELIONYMPHA RAINEYI, FROM BRITISH EAST AFRICA

BY

EDGAR A. MEARNS

(PUBLICATION 2059)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
NOVEMBER 28, 1911

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

DESCRIPTION OF A NEW SPECIES OF SUNBIRD, HELIONYMPHA RAINEYI, FROM BRITISH EAST AFRICA

By EDGAR A. MEARNS

Upon examining the first lot of birds sent to the United States National Museum by the Rainey African Expedition, I find the following apparently new species.

HELIONYMPHA RAINEYI, new species[1]

Rainey's Wedge-tailed Sunbird

Type-specimen.—Adult male, molting. Cat. No. 217483, U. S. N. M. Collected at the Telek River, Sotik District, British East Africa, May 16, 1911, by Edmund Heller. Original number, 136.

Characters.—In coloration almost exactly like *Cinnyris mariquensis suahelica* Reichenow, but with a much longer bill, shorter wing, and elongated pointed central pair of rectrices.

Description.—Pileum, cervix, mantle, and rump metallic golden green; wings brownish blue-black; upper tail-coverts bluish green; tail brownish black, the central feathers narrowly edged with green; chin and throat metallic golden green; upper chest with a transverse band of metallic blue, succeeded, posteriorly, by a broader band of brownish red; abdomen and crissum brownish black; bend of wing metallic green; axillars and under wing-coverts black. In dry skins the bill, feet, and claws are black.

Measurements of type (adult male).—Length (of skin), 138 mm.; wing, 66; tail (molting), 57; exposed culmen (chord), 22; tarsus, 17.

Measurements of adult male topotype (Cat. No. 217484, U. S. N. M.).—Length (of skin), 130; wing, 66; tail (molting), 49; exposed culmen (chord), 22; tarsus, 18.

Remarks.—This bird is most closely related to *Heliomypha erythrocerca* (Heuglin), but in coloration bears a closer resemblance to *Cinnyris mariquensis suahelica* Reichenow.

[1] Named in honor of Mr. Paul J. Rainey, in recognition of his services to biological science in connection with the Rainey African Expedition.

SMITHSONIAN MISCELLANEOUS COLLECTIONS

VOLUME 56, NUMBER 29

THREE NEW CLUB-MOSSES FROM PANAMA

WITH THREE PLATES

BY

WILLIAM R. MAXON

(PUBLICATION 2064)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
JANUARY 6, 1912

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

THREE NEW CLUB-MOSSES FROM PANAMA[1]

By WILLIAM R. MAXON

With Three Plates

In a previous paper[2] relating to a singular new fern (*Polypodium podocarpum*) from Panama, I have described very briefly the mountian region above David in the province of Chiriqui, and have referred in particular to a most interesting collecting trip of three days which I took from El Boquete over "Holcomb's trail" along the Rio Caldera to "Camp I" and to the summit of the Continental Divide a few miles farther on. The heavily forested mountain slopes are here intensely wet, and, as is usual under such conditions, a large proportion of the pteridophyta are epiphytes. Species of Lycopodium do not appear to be very common, but of the several collected three seem to have been hitherto unknown. These may be described as follows:

LYCOPODIUM FOLIACEUM Maxon, sp. nov.

Plate 1

A coarse, stout, diffuse epiphyte, probably of ascending growth, attaining a length of 40 cm., sporangiate without interruption in the upper third or half, the sporophyls similar to the foliar leaves but gradually smaller toward the ends of the branches. Stem very stout, woody, about 4 mm. in diameter at the base, 1 to 4 times dichotomous, the branches divaricate, about 2 mm. in diameter near the tips; leaves very numerous and close, borne in 10 ranks and by tortion somewhat dorsiventrally arranged, those of the 8 under and lateral ranks usually divergent at right angles (except in drying) or slightly ascending, twisted at the base, those of the 2 uppermost rows strongly reflexed, straight, all the leaves otherwise alike, symmetrical, rigidly herbaceous to subcoriaceous, oblong-elliptic to oblanceolate from a narrowly long-cuneate base (the base reddish-punctate below), thus sometimes appearing subspatulate, 10 to 13.5 mm. long, 2.5 to 4.5 mm. broad near

[1] This paper is the fifth dealing with the results of the Smithsonian Biological Survey of the Panama Canal Zone.

[2] Smithsonian Misc. Coll., Vol. 56, No. 24, pp. 1–4, pls. 1–3, November 22, 1911.

the middle, the margins strongly revolute, entire except at the minutely erose-denticulate, acute or short-cuspidate apex; costæ medial, percurrent, the leaf in drying sharply carinate upon the upper surface, the costæ sometimes evident below near the base, but usually indicated along the under surface of the leaf throughout merely by a shallow medial furrow; sporophyls conform, rarely more than 10 mm. long; sporangia reniform, about 2 mm. broad, protruding beyond the narrow bases of the sporophyls a distance of about 0.5 mm. on each side.

Type in the U. S. National Herbarium, no. 676073; collected from a fallen branch in humid forest along the upper Caldera River, near Camp I, Holcomb's trail, above El Boquete, Chiriqui, Panama, altitude about 1650 meters, March 23, 1911, by William R. Maxon (no. 5628).

The specimens here described were found upon a large limb which had been broken off from an enormous forest tree upon the steep slopes above and partially obstructed the trail at a point not far above Camp I. The species is very different from any reported previously from North America, and from any South American species known to me. It is a coarse, "bushy" plant and, when in a fresh condition, very heavy. Though not succulent it was long in drying, and then very rigid. The arrangement of the leaves can scarcely be made out except by soaking the plant in water, when the number of ranks of leaves, the twisting of all but those of the two upper rows, and the reflexed position of the latter are features which become readily apparent. Including the spreading leaves the diameter of the larger stems is from 2.5 to 3 cm. The apparent abundance of leafy covering, which has suggested the specific name, is even more pronounced in the living than in the dried specimens.

LYCOPODIUM STAMINEUM Maxon, sp. nov.

PLATE 2

Plant about 20 cm. long, 3 times dichotomous (probably repeatedly so in larger specimens), the stem relatively stout, about 1.5 mm. in diameter at the base, 1 mm. in diameter near the apex, more or less succulent, flattened in drying; leaves rather crowded in attachment, borne apparently in 10 ranks, spreading at right angles to the stem, filiform, acicular in the outer part, 10 to 17 mm. long, 0.2 to 0.3 mm. broad, bright red at the base (at least upon the under side), the margins entire and in drying curved inward over the upper surface, the leaves thus broadly concave above or even subtubulose; plant fertile in the upper third, the sporangia borne in alternating zones,

the sporophyls exactly like the foliar leaves; sporangia reniform, 1.2 to 1.3 mm. broad, thus protruding beyond the base of the sporophyl a distance of about 0.5 mm. on each side.

Type in the U. S. National Herbarium, no. 676085; collected from a tree trunk in humid forest of the upper Caldera watershed between Camp I and the Divide, Holcomb's trail, above El Boquete, Chiriqui, Panama, altitude about 1750 meters, March 23, 1911, by William R. Maxon (no. 5636).

Only three plants of the present species were observed, these growing together; the largest has served for the description. Presumably the plant attains a greater size than shown by the specimens at hand; but even this small amount of material is ample to indicate the marked peculiarity and distinctness of the species. The leaves are truly capillary and mark it as the narrowest-leaved species yet discovered in tropical America. It is a member of the section Selago, and is related (though not at all closely) to *L. pithyoides* Schlecht. and Cham., of Mexico, Guatemala, and Cuba, a species which is equally well marked by its stout woody stems and very much longer, bisulcate, reflexed leaves about 1 mm. broad.

LYCOPODIUM WATSONIANUM Maxon, sp. nov.

PLATE 3

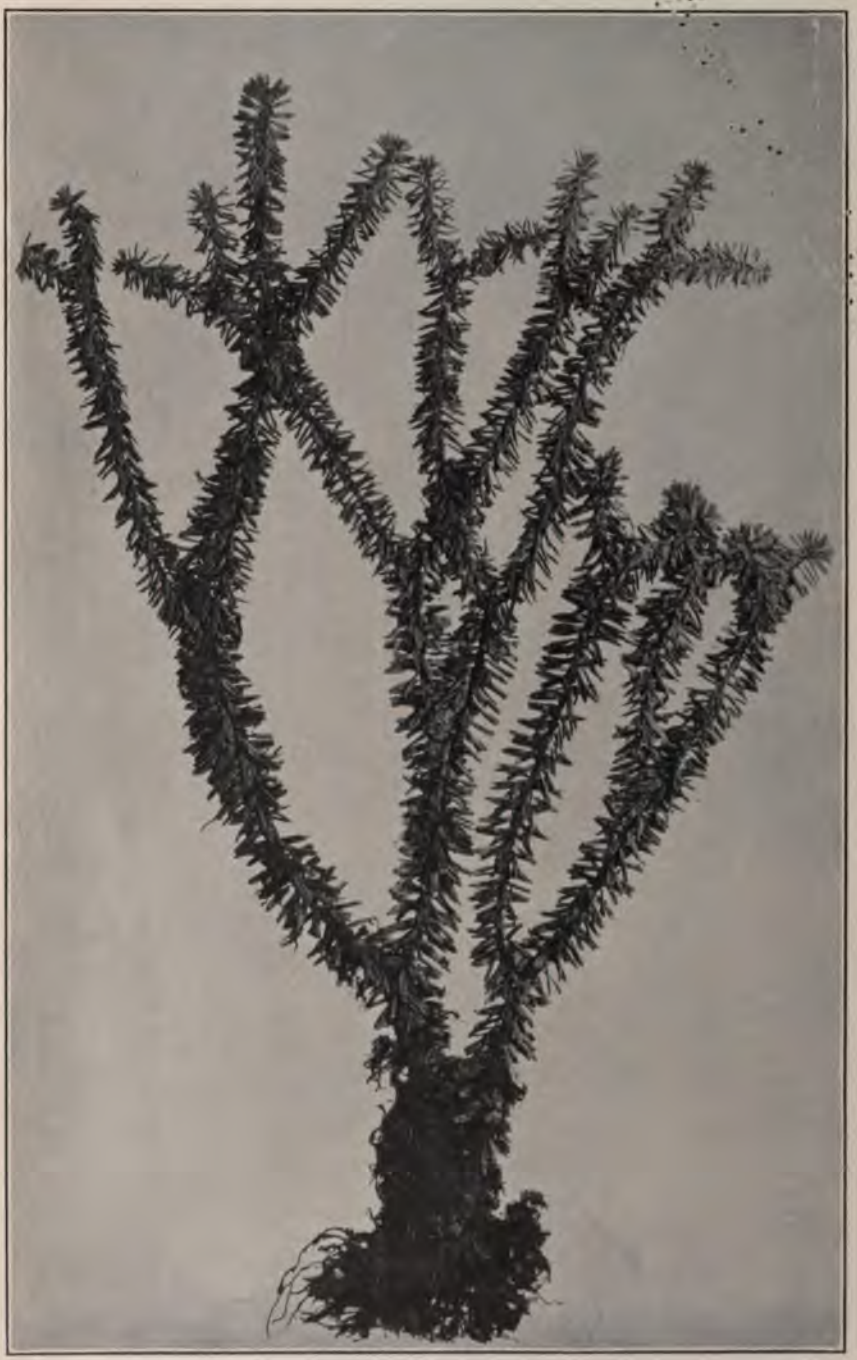
A slender pendent epiphyte, 35 cm. long, about 8 times dichotomous, interruptedly sporangiate in the upper third. Stem delicate, 0.5 to 0.7 mm. in diameter, yellowish green like the whole plant, the branches slender, unequally developed (perhaps through injury), forked at a slight angle; leaves numerous but not close, borne in 8 ranks, in the dried plant appearing almost whorled, divergent to obliquely ascending, mostly falcate, slender but very rigid, thick, linear-acicular from a slightly broader base, 5 to 8 mm. long, 0.4 to 0.5 mm. broad at the base, 0.3 to 0.4 mm. broad below the middle, or much narrower by the curvature of the margins, entire, all twisted at the base, the upper surface slightly convex, the lower surface broadly or sometimes deeply concave, the leaf in drying not infrequently subtubulose or irregularly plicate, the costæ very slender, concealed, or evident only by transmitted light as a whitish line; sporophyls in alternating zones 1 to 1.5 cm. long, averaging shorter than the foliar leaves (4 to 5 mm. long), linear-acicular from an irregularly ovate to broadly deltoid base (this 0.7 to 1 mm. broad), the margins here undulate to irregularly and bluntly erose-dentate, elsewhere entire; sporangia reniform, partially concealed by the expanded bases of the sporophyls.

Type in the U. S. National Herbarium, no. 676223; collected from the trunk of a small forest tree in humid forest along the upper Caldera River, near Camp I, Holcomb's trail, above El Boquete, Chiriqui, Panama, altitude about 1600 meters, March 24, 1911, by William R. Maxon (no. 5712).

FIG. 1.—Bases of Sporophyls.

L. Watsonianum is of the section Selago and the group of *L. linifolium*, but is not closely related to any North American species. The leaves are harsh to the touch, and the branches remarkably rigid for so slender a plant. The irregular expanded bases of the sporophyls, an unusual feature for this group of species, are indicated in the text-figure herewith.

Dedicated to H. J. Watson, Esq., a resident of El Boquete, who during the last twenty years not only has been of very great assistance to naturalists visiting the mountain region of Chiriqui, but has himself made extensive zoölogical collections.



LYCOPODIUM FOLIACEUM Maxon
(TWO-FIFTHS NATURAL SIZE)

LYCOPODIUM STAMINEUM Maxon
(NATURAL SIZE)

Digitized by Google

LYCOPODIUM WATSONIANUM Maxon
(ONE-HALF NATURAL SIZE)

PEARL RIVER

SMITHSONIAN MISCELLANEOUS COLLECTIONS

VOLUME 56, NUMBER 30

A NEW SUBSPECIES OF PTARMIGAN FROM THE ALEUTIAN ISLANDS

BY

A. C. BENT

(PUBLICATION 2066)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
JANUARY 6, 1912

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

A NEW SUBSPECIES OF PTARMIGAN FROM THE ALEUTIAN ISLANDS

By A. C. BENT

The new subspecies of Ptarmigan here described was collected at Tanaga Island, Alaska, during a brief visit to the Aleutian Chain in the summer of 1911 for the purpose of gathering material for the continuation of the work on the Life Histories of North American Birds, published by the Smithsonian Institution several years ago. The subspecies is named in honor of Dr. Leonard C. Sanford, of New Haven, Conn. Good series of this bird and of its nest were collected. Near the beach and on the tundra of Tanaga Island the birds were abundant and tame.

LAGOPUS RUPESTRIS SANFORDI, new subspecies

Tanaga Ptarmigan

Subspecific characters.—Similar to *Lagopus rupestris chamberlaini*, Clark, and to *L. r. atkhensis*, Turner, but much lighter than either, especially on the throat and breast, the darkest specimens of *sanfordi* being somewhat lighter than the lightest specimens of either of the other forms and the average difference being well marked and fairly constant. Less heavily barred with black on head, throat and chest; black loral space less conspicuous; and with fewer black markings in feathers of back.

Description of male.—(Type, adult male, Cat. No. 222527 U. S. Nat. Mus., Tanaga Island, Aleutian Chain, Alaska, June 25, 1911. R. H. Beck.) General tone of the summer plumage light greyish buff, paler on the throat, chest, rump and upper tail-coverts than elsewhere.

Ground colors of upper parts varying from pale clay color or wood brown in the darkest birds to very pale drab grey, almost whitish, in the lightest birds; generally all of these and several intermediate shades of color showing on different feathers scattered indiscriminately over the back, scapulars and rump. The lightest feathers tipped with whitish, having irregular subterminal black bars and finely sprinkled with minute black dots. The darkest feathers ochraceous or clay-colored, with large central black spaces and irregularly barred or vermiculated with black. Feathers of intermediate colors more or less barred or sprinkled with black.

Central tail feathers wood brown, more or less finely sprinkled with black. The lateral rectrices dull seal brown, more or less variegated basally on the outer web with broccoli brown more extensively towards the center of the tail. Chin and upper throat dull white tinged with buff, sometimes heavily spotted with black. Breast and sides varying from very pale buff to ochraceous buff finely vermiculated with black. Abdomen, under tail-coverts, feet and wings white. Shafts of primaries dusky, usually with a median dusky streak, which in some specimens occupies more than half of the width of the web and in others is scarcely visible. The supraorbital comb is highly developed and varies in color from flame scarlet to orange vermilion. Measurements of type: wing 197, tail 108, tarsus 33 and culmen 18 millimeters.

Description of female.—Upper parts, including head, back, scapulars, upper tail-coverts and central rectrices, variegated with shades of ochraceous, clay color, buff and pale wood brown, heavily and irregularly barred with black; many feathers on the hind neck, back, scapulars and rump have large central black spaces and very broad black bands. Under parts, from which all white disappears in summer, uniform rich ochraceous buff, barred on the breast and sides with black, sparingly barred on the abdomen and but sparingly spotted on the throat. Wings white, primaries marked as in the male. Tail similar to that of the male. Supraorbital comb smaller and duller than that of the male.

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 56, NUMBER 31

REPORT ON AN INVESTIGATION OF THE GEOLOGICAL STRUCTURE OF THE ALPS

BY

BAILEY WILLIS

(PUBLICATION 2067)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
FEBRUARY 7, 1912

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

REPORT ON AN INVESTIGATION OF THE GEOLOGICAL STRUCTURE OF THE ALPS.[1]

By BAILEY WILLIS

Eight years ago I first had the pleasure of meeting Prof. Maurice Lugeon on the memorable occasion of his striking address and remarkable triumph at the Vienna Congress of Geologists in 1903. The subject of overthrusts which he then discussed so graphically and with so much force was not unfamiliar to me, that type of structure having been recognized first by the American geologist Rogers, whose observations I had had occasion to verify. I was, therefore, fully prepared to accept the view that the Alps had been overthrust. I did not then, and I do not now, doubt that they consist chiefly of overthrust masses. Nor do I question the amount of displacement. Even the greatest horizontal movements which are postulated to account for the various nappes that have been observed, are relatively small as compared with the long arcs of the earth's periphery, in which the movement must have originated; and the accumulated effect which we may observe in any case should not occasion doubt.

It is a pleasure to me to be able to agree with Prof. Lugeon in these fundamental conceptions of the importance and extent of overthrusting in the structure of mountain chains, and particularly of the Alps. I regret the more that there are differences of opinion between us as to the mechanics of overthrusts, and that this divergence of interpretation is such that I have not been able to accept his views on the structure of the Alps as cordially and fully as I should like to do. But, inasmuch as Alpine structure is one of the great types from which our science draws essential conclusions, I hold it to be important to reach a correct interpretation of it, and I have for some years assiduously endeavored to understand the basis of Prof. Lugeon's views and the grounds upon which they have been accepted generally by European geologists. Through the aid of the Smithsonian Insti-

[1] This investigation was carried on by means of a grant from the Smithsonian Institution in 1907.

tution, I visited, in 1907, certain critical districts in the Bernese Alps and was most courteously guided to significant localities in the Diablerets and near Château d'Eux by Prof. Lugeon and M. Jaccard. The observations which I was thus enabled to make confirmed my opinion that the visible structures must be essentially those which Prof. Lugeon had described as seen by him, but that his interpretation rests upon mistaken assumptions and is erroneous. The detail of his observations and the painstaking care with which they are made are worthy of the highest recognition, but, in my opinion, the purely hypothetical formula expressed in the conventional figure of a "pli-nappe" is incorrect.

In the interests of our science, I have sincerely hoped that Prof. Lugeon would explain the structure and movement of the "nappes de recouvrement" as he conceives them, and that his explanation would include such modifications of the accepted theory that it would not contradict the principles of mechanics. Particularly since the publication of the observations of Professor Rothpletz, in the section across Préalpes from Gurnigel to the Wildstrübel, it has seemed to me that the theory of the "nappes de recouvrement," involving the concepts of the "racine," the "carapace," and the "tête," must be justified or corrected. But, so far as I know, no adequate answer to Professor Rothpletz, nor any searching study of the mechanics of the "pli-nappe," has been made.

There is good ground, in my opinion, to question the following assumptions or inferences of the currently accepted theory of Alpine structure:

(1) That the overthrust masses of the Alps have all moved in one direction.

(2) That the so-called "racine" of a nappe de recouvrement is, in fact, the zone of origin of the thrust mass.

(3) That the supposed "tête" is that part of the structure which has advanced beyond the "carapace" and the "racine"!

(4) That the succession of overthrusts in the Bernese Alps has been as described, either in relations of space or time.

From the observations which I made in 1907, I infer that:

(1) Overthrusting in the zone of the Préalpes and Bernese Alps has proceeded at different epochs from opposed directions: namely, earlier from the northwest, later from the southeast.

(2) The so-called "racine" of the pli-nappe of the Wildhorn-Wildstrübel is, in fact, the southern and farthest advanced remnant of an overthrust from the northwest.

(3) The isolated masses of pre-Eocene strata, which have been called remnants of the tête or front of the same pli-nappe, and others which I saw near Château d'Eux, have been cut off by intersecting overthrusts. They first moved southward or southeastward and later northward or northwestward, in both movements rising on the inclined thrust planes. Their present position is thus above but not distant from that which they originally occupied. The same is true of the so-called "exotic" masses of the Préalpes which constitute the "têtes" of the hypothetical nappes des Klippes.

(4) The thrust which divides the pli de Morcles from that of the Diablerets is a minor thrust plane rising from a major thrust plane that underlies the Hautes-Alpes, and is one of a system of minor thrusts which, with the major thrust, constitute a single complex structure of the Scottish Highland type.

(5) Since the principal concrete example of a "pli-nappe" or nappe de recouvrement, that of the Wildhorn-Wildstrübel, is, according to my observation, not a pli-nappe but an effect of two intersecting thrusts, I am unable to accept the reconstruction of less complete nappes de recouvrement, which, according to modern theory, were once piled up, one overriding the other, to form the Alps. I regard it as probable that the recognition of intersecting overthrusts and of systems of major and minor thrusts of the Scottish type, combined with unusual but incidental folding, will eventually be found to explain a large part of Alpine structures.

The observations which led me to these views were as follows:

First, as to the existence of thrusts from opposed directions. The evidence of that fact I first observed near Lenk, in the valley and heights, up to and including the base of the Wildstrübel. It is stratigraphic, structural, and physiographic. For identification of strata in the field on paleontologic evidence I am indebted to Professor Rothpletz, whom I chanced to meet at Zweisimmen and with whom I examined the locality. We there discussed and verified our observations of structure. The physiographic relations, which had great weight with me because I had seen similar effects in the Lewis Range of Montana, were unfamiliar to him as a basis of inference, and may be regarded as an independent line of reasoning.

The stratigraphy of the district of Lenk, which lies in the southern Préalpes, is well established. The Triassic, Jurassic, and Eocene are more or less fully represented by very distinctive formations which, in the order named, are essentially gypsiferous shales or gypsum (Triassic), blue marine limestone (Jurassic), and sandy brown shales

(the facies of the Eocene, commonly called "Flysch"). The Cretaceous is scarcely present, there being a marked hiatus between the Jurassic limestones and the earthy red lime-shales that correspond to its highest horizon. The Flysch, which was originally a very thick formation, has been thickened by folding and thrusting, so that it constitutes the dominant rock of the hills. The Jurassic limestone and the Triassic gypsiferous shales occur in the Flysch as fragments which have been separated from their original connections by thrusting.

The internal structure of the Flysch is obscured by sward, but its principal features may be traced by the fragments of pre-Eocene formations. Where Jurassic or Triassic rests upon Flysch, the contact of the older upon the younger formation is obviously a thrust plane. Where two or more such contacts, though somewhat apart, fall into a common plane of dip, they may reasonably be connected as belong-

FIG. 1.—Diagram of intersecting thrusts observed near Lenk and in the Wildstrübel.

$AA'A''A'''$ = plane of a major thrust from the northwest. $B, B, B,$ = minor thrusts branching from the major thrust AA' and belonging to one system with it. CC' = thrust from the southeast, intersecting and disturbing the older thrust $AA'A''A'''$. DD' and $D''D'''$ = surface of erosion developed after the thrust $AA'A''A'''$ and before the thrust CC'; dislocated by the latter and involved in the elevation of the Hautes-Alpes.

ing to one and the same thrust. And where several such planes lie parallel one to another, they form a system of thrusts; such, for instance, as that diagrammatically represented by the minor thrusts *B, B, B* in Fig. 1.

Near Lenk, in the hills which rise on each side of the valley that is eroded across the strike, this structure is clearly represented by the fragments of Jurassic limestone that form little scarps in the smooth grass-grown slopes of Flysch. Having traced out the several parallel thrusts on one side of the valley, one may identify each one on the other side by corresponding features of the hills and slopes. This Professor Rothpletz and I did, and we observed that the planes of these parallel thrusts dip northwestward at moderate angles. Our observations

have been fully described by Professor Rothpletz in the article already referred to. (See p. 2.)

Beneath the valley and adjacent hills is a thrust plane which is nearly horizontal. It is exposed near Lenk in the very bottom of the valley, and has long been recognized by Swiss geologists as one of the major structural features of the "zone des Cols" and of the "Niesen." We observed that the Flysch at this contact rests upon the nummulitic Eocene; that is to say, that the terrigenous sandy shales had been thrust upon the marine limestone of the same general period.

The relation of this nearly horizontal thrust plane to those which, at steeper inclinations, traverse the hills on either side is that of a major thrust to minor thrusts of the same system, as shown by *B*, *B* to *AA'*, Fig. 1. The general dip is northwestward. In that direction the minor thrusts join the major thrust and the system is represented farther northwest by other minor thrusts.

In a region like the Alps, where thrust planes have been folded, the direction of thrusting cannot safely be inferred from the dip of a single plane. But granting this, it is quite a different matter when the inference rests on the agreement of several minor thrusts and the major thrust from which they spring. The system of major and minor thrusts to be seen at Lenk demonstrates that the Flysch of that region and the fragments of older strata included in it moved from northwest toward southeast.

This observation is surprising, because it is in such marked contradiction to the fact that European geologists have in recent years given up the idea of movements from the north or northwest. They appear to have abandoned the field too readily to those who assert that the Alps have been pressed northwestward only. At Lenk there is clear evidence of southeastward movement.

It will be necessary to identify this mass which has been thrust southward, in its southern extension. But before doing so, it is desirable to refer here to the great thrust that underlies the Wildstrübel and other portions of the Bernese Hautes-Alpes (*CC'*, Fig. 1). It is, of course, well-known. With the superb recumbent fold which is so magnificently exposed in the face of the Wildstrübel, it constitutes a most striking example of that structure which is now described as a "pli-nappe," and which Rogers first recognized in the Appalachians as an overturned anticline and reversed fault. Heim elucidated the mechanics of the structure. It has been experimentally reproduced. The overturned anticline precedes displacement on the thrust plane when a couple of opposed forces develops in strata in

the zone of moderate load and folding; but when dislocation originates in the deeper zone, where excessive load prevents competent folding, the movement, on being transmitted to strata in the zone of folding, may produce a recumbent anticline as an incidental structure. Displacements of the former class are usually of moderate horizontal throw, rarely more than ten or twenty kilometers, but they may be features of a very extensive general movement. Such I take this pli-nappe of the Wildstrübel to be: an overturned anticline which has been pushed far enough to dislocate the middle limb, although not necessarily to a great distance. It is, however, a striking feature of the pronounced movement of the mass of the Alps from southeast toward northwest. Since there is no question of this movement toward the northwest, we may accept it without discussion.

I must here advert to the difference of facies between the strata of the Préalpes and those of the Hautes-Alpes. The former is an incomplete sequence, comprising but a few of the Mesozoic stages and the Eocene. The latter is a very complete succession from Triassic to Eocene inclusive. The one is composed chiefly of sands and muds, the other of marine limestones. The contrast could scarcely be more marked.

Accepting this well-known distinction, we may say that the two facies are superimposed, each on the other, by the thrusts from opposite directions. The Flysch of the Préalpes, in being thrust toward the southeast on the major thrust plane, came to rest on the surface of the marine nummulitic Eocene of the facies of the Hautes-Alpes. This contact is seen in the valley floor near Lenk, as already described. The marine strata which form the Hautes-Alpes may, in turn, be seen superimposed on the Flysch at the base of the great cliffs which form the face of the Wildstrübel south of Lenk. The contact marks the thrust plane, which dips southeast and on which movement was toward the northwest.

Having become convinced, contrary to my expectations, but by my own observations, that the structures of this district comprise two intersecting systems of overthrusts, I sought to determine which might be the older system. The evidence on this point is unequivocal.

Going from Lenk southward to the base of the Wildstrübel one may observe that the major and minor thrusts of the system on which displacement was southward rise in the hills. Near Lenk the planes dip nearly uniformly. Near the base of the Wildstrübel they are folded into anticlinal and synclinal structures. Although long fa-

miliar with folded thrust planes as they occur in the Appalachians and have been described by Keith, I have never elsewhere seen such clear and convincing examples as are to be found here. The anticline of the Iffigental, which shows a superb arch of Jurassic limestone overlying the Eocene Flysch, is without an equal in my experience for perfection and simplicity; and the folded thrust planes of the foothills north of the Wildstrübel (Oberlaubhorn and Laufbodenhorn), though more intricate, are no less clearly defined. At the immediate base of the Wildstrübel the disturbance of the thrust planes is more intricate and minute. They are affected by shearing as well as by folding; and tracing these minor secondary structures directly to the great overthrust on which movement was from the opposite direction, one cannot doubt that they were produced by that movement. Hence, the thrust from the southeast is younger than that from the northwest.

A method of investigation which has been more widely adopted by American geologists than by those of Europe, is based upon the relation that may exist between structures, such as folds or thrusts, and the features developed by erosion. I know many mountain ranges whose internal structures are older than the erosion of the surface. I know others whose relief is an effect of relatively recent folding or thrusting. On examining the Préalpes and Hautes-Alpes with this relation in mind, I found a clear distinction between the movement from the northwest, which is older than any recognizable erosion of the region, and the movement from the southeast, which is younger than the earliest erosion cycle that I could recognize. The succession of events was: (1) movement from the northwest; (2) erosion to a mature stage, with moderate relief; (3) movement from the southeast, resulting in dislocation of the older structures and also of the mature erosion surface, together with the elevation of the Hautes-Alpes; (4) erosion of the younger features of topography as they now exist.

The observations which I made on these points were as follows:

In the Préalpes I detected features pertaining to two different cycles of erosion. The more recent is represented by the deep valleys and slopes of the present stage. The other is an older, mature surface, which may be seen in the long ridges and summits of the Préalpes. It is extensively and generally dissected by the later valleys, but there are many flat areas which are not the result of any structure or of any recent condition of erosion. They represent the lower levels of the mature surface in which the present valleys are

so deeply cut, and they are being destroyed by current activities. The hills that rose above these old levels were of moderate altitude, 200 meters, more or less, and were maintained by the relatively hard limestone fragments involved in the overthrust masses of the Flysch. The old topographic surface thus resulted from differential erosion of a region which had already been disturbed by movement from the northwest. The thrusts had brought up the limestone fragments, but any ridges which may initially have been produced by thrusting had been eroded and replaced by hills adjusted to the the relatively harder rocks. This mature topographic surface is well seen in the Hahnenmoos and surrounding hills above Lenk, and may be recognized from that point of view as an obvious landscape of the summits of the Préalpes.

A mature erosion surface of parallel development to that just described is to be seen in the Hautes-Alpes. I would cite the ice-covered flat of the Plaine Morte as an illustration of its development in the Wildstrübel. This basin, though now the gathering-ground of a glacier, is not due to glaciation; nor is it due to structure of the rocks. It is an erosion surface of gentle grade, with more or less surviving relief worked out before it was elevated to its present position. Where it now lies, its destiny is to be cut to pieces by the development of ravines in the mountain mass of the Wildstrübel. It lies a thousand meters above the homologous surface in the Préalpes and is separated from it by the thrust plane on which the Wildstrübel moved northwestward. The thrust plane rises in that direction; the mass of the Wildstrübel must have been raised in advancing up the incline, and the altitude of the Plaine Morte above its homologue in the Préalpes may, with reason, be attributed to that upward movement.

From these relations I draw the conclusion that the thrusting from the southeast occurred after the erosion cycle had advanced to maturity on the overthrust masses that had previously approached from the northwest.

Since structural and physiographic evidences show that the more recent thrusting was from the southeast, we are led to look for displacement of the older structures by the younger. I have already described the folding of the older thrust planes at the base of the Wildstrübel on the northern side of the younger thrust, by which they are there cut off. When we cross to the southern side of that younger thrust any part of the older major thrust which may exist on that side must lie at some higher level in the elevated mass of the Wild-

strübel. It is found in the summit and is traced down the southern slope to the valley of the Rhone.

This statement rests upon Prof. Lugeon's own observations. He has traced this overthrust from the Rhone valley over the Wildstrübel to the Préalpes near Lenk, and has identified the overthrust mass as a nappe de recouvrement having its "racine" in the Rhone valley, its "carapace" on the summit of the Wildstrübel, and its "tête" near Lenk. We may accept the identification of the several sections as parts of a whole structure, for it rests upon that detailed stratigraphic and structural study which Prof. Lugeon has pursued with minute care. But, misled by the erroneous assumption that thrusting proceeded from one direction only, Prof. Lugeon has, I believe, mistaken the relations of the parts to the whole. The so-called "racine" is the tête and the "tête" is the racine, if we can apply these terms at all. The great major thrust from the northwest can be recognized from Lenk to the base of the Wildstrübel and from the summit of the Wildstrübel to the Rhone valley. It is dislocated between the base and the summit of the Wildstrübel by one younger thrust from the southeast, and is finally cut off by another south of the Rhone.

Having been obliged by my observations to recognize the preceding statement of the structure of the Préalpes and Hautes-Alpes as correct, and feeling sure that the concept of superimposed "pli-nappes" or "nappes de recouvrement" should be replaced by an explanation based on intersecting major thrusts, minor thrusts, and folds, I ventured to consider the supposed sequence of pli-nappes which Prof. Lugeon has described as forming the Hautes-Alpes from the Rhone valley eastward. He distinguished the "pli de Morcles," the "pli de Diablerets," and the "pli de Wildhorn-Wildstrübel," and others, in the order named from west to east, and showed that the pli de Morcles pitches under that of the Diablerets, the latter pitches under the pli-nappe of the Wildstrübel, and so forth, each folded and overthrust mass disappearing under the one to the east of it. I accept this observed structure, a portion of which I had the pleasure of seeing with Prof. Lugeon in an excursion to the Diablerets. According to the current interpretation, which I cannot accept, each of these pli-nappes developed as a distinct overthrust, one after the other, each older one having a "racine" south of the next younger, and each having been thrust over the preceding. They would thus have been piled up, as shown in various hypothetical sections, in such, for instance, as profiles I to IV of the Géologie de la Suisse, by Dr.

Schardt.[1] The total altitude would then have been not far from 12,000 meters.

Were this view correct, there must be a notable difference in age between the successive overthrusts, and particularly between the earliest and latest of the series. Since they have been exposed to erosion, and by hypothesis some have been exposed longer than others, we should expect the older masses to be more eroded then the younger; as, for instance, in the case of older and younger volcanoes of the Canary or Hawaiian Islands. Such is not the case in the Alps. The Hautes-Alpes constitute a physiographic unit, although they are structurally complex. Considering them for the moment also as a structural unit, and recalling the great recent thrust plane up which they have advanced as a whole from the southeast, we may recognize that the altitude of the chain above the Préalpes is due to the rise on the inclined thrust plane, while the superb scarp which they present to the northwest and north is the effect of consequent erosion on the front of the rising mountain mass. This scarp is of uniform physiographic age from one end of the chain to the other, it being everywhere in a stage of extreme youth.

Having studied a similar scarp and structure in the Lewis range of Montana, where Pre-Cambrian rocks were overthrust on Cretaceous, probably during the Miocene, I judge by comparing the effects of erosion in the two mountain ranges that the elevation of the Hautes-Alpes by advance on the thrust plane occurred not earlier than the Pliocene and possibly in the early Quaternary. However this may be, the scarp is very young, and uniformly young from end to end.

At certain points a lesser scarp branches from the great front of the range and turns back into the heights. As the front faces north by west, these lesser ones face westerly. They also are physiographically young. Indeed, they are distinguishable from the great scarp only by their branching off and having less altitude. Each of these minor scarps is the western face of a segment of the range which Prof. Lugeon has described as a distinct pli-nappe. The cliffs of the Diablerets thus overlook the segment which is called the pli de Morcles. Each minor scarp is based on a thrust plane, dipping easterly, just as the major scarp is based on the major thrust dipping southeasterly. Each minor scarp is related to its minor thrust as the major scarp is related to the major thrust. They all form one system and are of one and the same age.

[1] Schardt, H.: Géologie de la Suisse, article extrait de "La Suisse"; Publications de la Dictionnaire Géographique de la Suisse, Neuchatel, 1908, pls. 22-23.

Thus I regard the Hautes-Alpes of the Bernese chain as consisting structurally of a great overthrust mass whose general movement was north by west or northwest on a major thrust plane. There developed simultaneously a number of minor thrusts on which movement was toward the west, at an angle to the general motion of the mass. It is an example of major and minor thrusting, with two somewhat divergent directions of displacement and with diversities of folding in the several segments.

It was at the suggestion of Prof. Lugeon that Dr. Jaccard courteously conducted me to the vicinity of Château d'Eux, where he showed me a typical example of the " tête plongeante " of a nappe de recouvrement in the Rhetic limestone of the Pte. de Cananéen. The annexed diagram is taken from Dr. Jaccard's paper.[1]

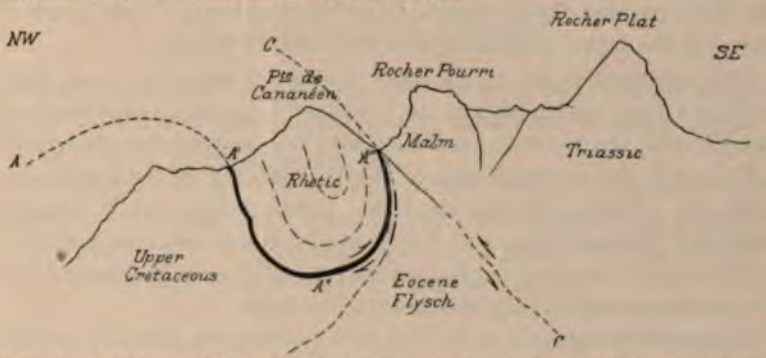


FIG. 2.—Préalpes near Château d'Eux. Characteristic " tête plongeante " of a supposed " pli-nappe " represented by the " Brèche de Chablais-Hornfluh " (Rhetic) infolded in Cretaceous and Eocene. Otherwise interpreted as a mass overthrust from the left (*NW*) on the plane *AA'A"A'"*, which now appears folded back by the later thrust *CC'* from the southeast. (Adapted from sketch by Jaccard, pl. 34.[1])

The limestone (" Brèche de Chablais-Hornfluh ") is of Rhetic age, according to Jaccard, and the fragment that forms the Pte. de Cananéen is an isolated synclinal mass, resting upon and enveloped in Upper Cretaceous strata, which in turn overlie the Eocene Flysch. In this inverted order and synclinal structure we may certainly see the plunging head of a great overthrust sheet that has come over all the Alps from the far southeast and buried itself in the Flysch—if such a head and such a sheet have, or possibly could have, any actual existence. I could not, however, accept that concept. I saw, instead,

[1] Jaccard, Frédéric: La Région Rubli-Gummfluh; Bull. de la Société Vaudoise des Sciences Naturelles, Vol. 43, 1907, pl. 34.

a complex thrust, composed apparently of two related planes, which had been folded back upon itself in a later movement from the opposite direction. The later movement had also resulted in a thrust, dislocating the former one and superimposing the Jurassic and Triassic strata of the Rocher Pourri and the Rocher Plat upon the Eocene and the Rhetic mass infolded in it. To the southeast of the Rocher Plat we crossed another fragment of the Brèche de Chablais-Hornfluh, also superimposed upon the Flysch by thrusting from the northwest, and observed that the thrust plane was closely folded and cut off by the Jurassic of the Gummfluh, again overthrust upon it by the later movement from the southeast. (See the sections in Jaccard's paper, pls. 36-38.)

The structure involves one thrust plane from the northwest and two later parallel thrust planes from the southeast. The strata involved in the movements have also been closely folded.

This structure is one of the most complex I have ever seen, and I could not have understood it, as I believe I do, had I not been prepared by the observations on folded and intersecting thrusts which I had made at the northern base of the Wildstrübel, in the Laufbodenhorn, etc. During the two days that I was guided by Dr. Jaccard, between Château d'Eux and Zweisimmen, I saw repeatedly the evidence of older thrusts from the northwest and of younger thrusts from the southeast intersecting and dislocating them.

In the tête plongeante of the Pte. de Cananéen we have an excellent illustration of the structure of those masses which were described by Querreau and later by Prof. Lugeon as being isolated and "without roots." To satisfy myself on this point, I studied the Mythen above Schwyz, and the Brèche de Hornfluh near Zweisimmen. I have no doubt that these masses and others described by Prof. Lugeon, including the Brèche de Chablais, are actually underlain throughout by younger strata and are without any connection with the like formations in place. It is well known that some of these isolated masses, those of the Klippes, are "exotic"; that is to say, no strata of the same facies have ever been found in place. Hence, it is supposed that they must have come from a distant zone south of the Alps. An earlier and, I think, a more correct view was that they came from strata deposited in the zone of the Préalpes, where they are now found. That view was discarded because there was no explanation of the manner in which these isolated masses might have risen through and have become superimposed upon the younger (Eocene) strata which now so widely cover that zone. But let us consider the mechanical effects of intersecting thrust planes.

Let a rock mass start at a and be thrust to a'. Then let a later thrust carry it to a''. It will be isolated by two thrust planes and will be superimposed on younger strata more or less nearly over the place from which it started. One has but to think of a person mounting a stairway which turns back on itself. The " exotic " masses have

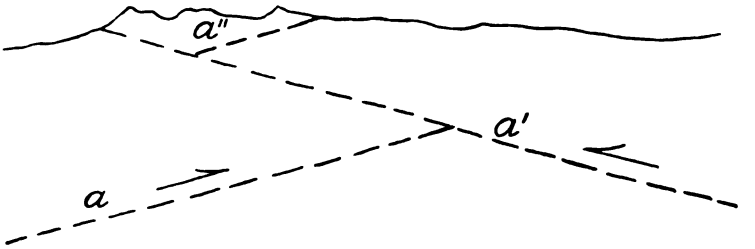


FIG. 3.—Intersecting thrust planes.

gone upstairs, some in one direction only, some in two; and the strata have been folded and squeezed into most complex and irregular forms in the successive movements.

In conclusion I desire to express my appreciation of the able and painstaking investigations of Prof. Lugeon, and to repeat an expression of regret that it is impossible for me to accept the theories of structure which have been developed from his studies.

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 56, NUMBER 32

Notes On Birds Observed During A Brief Visit to the Aleutian Islands and Bering Sea in 1911

BY

A. C. BENT

(PUBLICATION 2068)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
FEBRUARY 12, 1912

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

NOTES ON BIRDS OBSERVED DURING A BRIEF VISIT TO THE ALEUTIAN ISLANDS AND BERING SEA IN 1911

By A. C. BENT

I. Introduction

At the suggestion of Dr. Leonard C. Sanford, of New Haven, Conn., and with his financial assistance, I undertook to organize and conduct an expedition to the Aleutian Islands during the season of 1911. It was our intention to charter a suitable vessel and spend the entire summer in making a thorough biological survey of the whole Aleutian chain, exploring all of the larger and more important islands as thoroughly as the time and the facilities at our disposal would permit. But since the Biological Survey of the Department of Agriculture desired to cooperate with us and to send a man to collect for them, and as the Smithsonian Institution was interested in helping me secure material for additional volumes of the publication on Life Histories of North American Birds, it seemed best to make it a government expedition and accept the courtesy of the Treasury Department in offering transportation on a revenue cutter. We therefore abandoned our plans for a private expedition and the revenue cutter *Tahoma* was detailed to care for our party, which consisted of Rollo H. Beck, of San Jose, Cal., Alexander Wetmore, of Lawrence, Kan., Fred B. McKechnie, of Boston, Mass., and the writer.

We sailed from Seattle on May 19, and took the inside passage north to Ketchikan, where we remained a few days to take on some spar buoys, and from there we sailed out through Dixon Entrance and nearly west across the Pacific Ocean to Unimak Pass. We entered the Pass on June 4, anchored for one night at Akun Island and reached Unalaska on June 5. After discharging our cargo and coaling, we started on the western trip among the Aleutian Islands on June 10, with orders for the *Tahoma* to return to Unalaska on July 1. This gave us less than three weeks in which to explore over 800 miles of difficult islands, an undertaking for which three months would have been hardly time enough. We cruised the whole length

of the chain, however, and landed on Atka, Kiska, Attu, Tanaga, and Adak islands, besides visiting the western end of Unalaska Island, landing at Chernofski. The whole time at our disposal was so short that we could devote but a very few days to each of these islands and our explorations were limited to such small portions of them as we could reach on foot, which meant a small area within one day's walking distance of the most frequented or best harbor, where we were obliged to anchor. Long trips into the interior, which would involve camping, were not attempted; our time was too limited to waste any of it in making and breaking camp; we were not familiar enough with the region to know where to go and we had no facilities for transporting our camp outfit, supplies, and provisions over the endless succession of barren mountains surrounding every harbor, as there were neither navigable streams nor trails.

Our reconnaissance of the Aleutian chain was necessarily so superficial and hurried that it seems best to make at this time merely a brief report of the results and not to attempt to fully describe the topography, the flora, and the fauna of these interesting and little known islands until a more complete biological survey can be made by some subsequent expedition.

In spite of the short time at our disposal, the four members of our party used the excellent facilities at our command to the best advantage, and by constant hard work accomplished very satisfactory results. Much credit is due to the officers of the *Tahoma*, who gave us most valuable assistance and did everything in their power to further the objects of the expedition. Special thanks are due Chief Engineer John I. Bryan, Lieutenant John T. Carr, Lieutenant Herbert N. Perham, and Doctor Louis Schwartz, for much valuable assistance in securing specimens.

Good series of all the land birds were collected on nearly all of the islands visited; particularly fine series of the various subspecies of ptarmigan were taken, about forty from each of the important islands, among which a new subspecies was discovered inhabiting Tanaga Island, *Lagopus rupestris sanfordi*;[1] two species, hitherto unrecorded from North America, were collected, namely, *Calliope calliope* and *Hypocentor rustica*.

Some other interesting facts were learned regarding the distribution and habits of the birds of this region, but so much important work in this line still remains to be done that further and more thorough explorations would well be worth while.

[1] Described in Smithsonian Misc. Coll., Vol. 56, No. 30, December, 1911.

II. Birds Noted in the Aleutian Islands in June, 1911

GAVIA IMMER

Loon

Loons were noted at various islands, generally flying high in the air and too far off to identify. One, positively identified as this species, was seen flying across the bay at Adak Island on June 26, and one at Attu Island on June 23.

GAVIA PACIFICA

Pacific Loon

GAVIA STELLATA

Red-throated Loon

Small loons were seen flying in the distance on several of the islands where both of these species are found, though the Red-throated Loon is probably the more common one. I do not seem to have any positive records of any of these being definitely identified and none were shot. One or both of these species were undoubtedly breeding on nearly all of the larger islands where there were suitable ponds.

LUNDA CIRRHATA

Tufted Puffin

Immense numbers of this Puffin and a few of the following species were seen in the water as we were entering Unimak Pass, where they were scattered about over a large area, mostly singly, or in pairs or small groups. There were thousands of them dotting the water in all directions as far as we could see. We saw a few Tufted Puffins about nearly all the islands among which they were generally distributed, but we found only one breeding colony of any size, on a small rocky islet in Nazan Bay, Atka Island. A cloud of these Puffins and a few Horned Puffins were seen flying about the islet, but they all flew off when we landed. We had seen them entering and leaving some inaccessible crevices in the steep rocky cliffs where they were probably nesting. They also had burrows in the soil on the top of the rock, but they had not laid in the holes we dug out. This was on June 15, but evidently most of them had not yet laid.

FRATERCULA CORNICULATA

Horned Puffin

This species was not so abundant as the preceding, but was seen quite regularly in small numbers at nearly all of the islands and was breeding throughout its range. At Atka Island, on June 15, we found a small breeding colony on one of the rocky islands in Nazan Bay

where we saw them flying into and out of inaccessible crevices in a precipitous rocky cliff. In habits and general appearance they closely resemble the common Puffins of the Atlantic coast. We had no time to devote to their study and did not make any efforts to secure their eggs, being too busy with other more desirable things.

ÆTHIA CRISTATELLA

Crested Auklet

We did not find this species so abundant as we expected among the islands, probably because we did not spend enough time at the proper places. We saw a few among the Puffins at the entrance to Unimak Pass and several flocks among the rafts of Least Auklets in the harbor at Kiska Island. The Crested Auklets flew in large compact flocks, often containing forty or fifty birds, and could be easily recognized by their larger size and wholly gray appearance.

Their manner of flight, size, color and crests have suggested the local name of "sea quail" from a fancied resemblance to the California Quail. They were apparently breeding among the masses of large loose rocks and boulders at the base of some high cliffs near the entrance to Kiska Harbor; we saw birds flying out and saw droppings and feathers in the remote crevices under the rocks, but their eggs were too well hidden to see and were entirely inaccessible under the large rocks.

ÆTHIA PUSILLA

Least Auklet

These interesting little birds, the smallest of the Alcidæ, were first seen at the entrance to Unimak Pass among the Puffins and other sea birds, which gave us our first impressions of Aleutian bird life. There were a number of small flocks constantly in sight, rising readily in front of the ship or diving like a flash if we came too near. But it was not until we reached Kiska Harbor that we saw them in real abundance. One smooth foggy afternoon Mr. Beck and I took the skiff and went out towards the entrance of the harbor to collect sea birds. In the outer harbor we found Least Auklets congregating in immense flocks on what was probably their feeding ground. There were thousands and thousands of them swinging about us in great clouds like swarms of bees, or mosquitoes, and great rafts of them sitting in the water. Their diminutive size, short chunky bodies and the rapid motion of their little wings suggested bumble bees rather than birds as they bounced along over the little waves in their haste to get away. They kept up a constant twittering which from such a

vast multitude of birds created quite a volume of sound. They dove like lightning, disappearing so quickly that I could not see how it was done; but I saw them swimming under water using their wings and progressing rapidly. They are sociable little fellows and if one was wounded one or two others would usually return and hover about it, or settle on the water near it. I think they were also nesting under the rocks at the base of the cliffs with the Crested Auklets.

SYNTHLIBORAMPHUS ANTIQUUS

Ancient Murrelet

These pretty little birds were more or less common in all of the harbors where we anchored, usually well in shore, in small flocks of from four to six birds, swimming rapidly in compact flocks, but usually so lined out that not more than one could be killed at a shot. When hard pressed they dive by plunging quickly forward, sometimes, when greatly alarmed, jumping clear out of the water and diving head first. They do not remain under long and suddenly appear on the surface without causing a ripple. They have a shrill, faint whistling note.

We did not find their breeding places but the natives at Nazan Bay, Atka Island, had eggs which they had taken from holes in the cliffs at no great distance.

CEPPHUS COLUMBA

Pigeon Guillemot

This western counterpart of our eastern "sea pigeon" was seen in all suitable localities among the various islands, called by the same name and similar in habits to our eastern bird. The black markings in the white wing patches were quite conspicuous as field marks.

Wherever there were loose rocks piled up on the beaches around the harbors, we saw these Guillemots flying out from the shores and circling about us close to the water or sitting in little groups on the rocks, under which their nests were too well hidden for us to find, or too inaccessible to reach without the help of several men with crowbars. They were particularly numerous about the rocky shores of Kiska Harbor on Kiska Island, where the Least and Crested Auklets and Pacific Eiders were breeding. The breeding birds were in full summer plumage but we saw many in the mottled changing plumage and shot one in practically full winter plumage as late as June 15. On June 18 one female was taken containing an egg ready for laying.

URIA TROILE CALIFORNICA
California Murre

Numerous Murres were seen in Unimak Pass and at various places among the Aleutian Islands, but probably most of them were of the following species, though some of them were undoubtedly of this species. Among the vast hordes of Pallas's Murres breeding on Bogoslof Island we recognized a few scattering pairs of this species, which could be easily identified by the lighter brown color of the heads and necks which were also more slender with longer bills. On the flat top of the high, rounded cliff at the west end of Bogoslof, the sides of which were covered with breeding colonies of Pallas's Murres, we found several small compact colonies of California Murres sitting on their eggs in close bunches of fifteen or twenty pairs.

No breeding colonies were found elsewhere among the Aleutian Islands, although they undoubtedly existed there.

URIA LOMVIA ARRA
Pallas's Murre

As the Brunnich's Murre differs from the common Murre of the Atlantic coast, so may the Pallas's Murre be distinguished from the California.

Pallas's Murre in flight looks shorter, thicker and darker and at close range the white on the cutting edges of the mandibles is conspicuous. It is the commonest Murre in Bering Sea and was seen at various points among the Aleutian Islands where it breeds. It was particularly abundant in the waters north of Unalaska Island, where large or small flocks were almost constantly in sight flying up to the ship and swerving off across the bow or around the stern within easy gunshot. They were flying to or from their great breeding grounds on Bogoslof Island, which can often be located in the prevailing fogs by noting the direction in which the Murres or "crow bills," as they are called, are flying. Our visit to Bogoslof Island was made on July 4, and it proved to be a most glorious celebration of the day, though not a gun was fired.

It was certainly one of the most wonderful bird colonies I had ever seen. Castle rock at the eastern end towered upward from two hundred to three hundred feet with steep, sloping sides and sharp pointed peaks of volcanic rock and loose debris, over which we could readily climb. The peaks, the steep cliffs, and even the gravelly and sandy slopes were literally covered with nesting Murres, countless thousands of them, probably several hundred thousand, perhaps a

million; their numbers were beyond our power to even estimate. As we approached near enough to disturb them, they came sweeping down the slopes in great clouds so thickly that it seemed as if we would be swept off our feet by the rushing tide of birds; in their haste to escape as they scrambled off their nests they sent a shower of eggs rolling down the slopes to be smashed against the first rock they struck; and many of the birds bounded helplessly along over the rocks and stones in their frantic efforts to rise; it was an easy matter to knock them over with sticks or even catch them in our hands. When once well a-wing they would circle about the rocks in bewildering clouds, a steady stream of swiftly flying birds; and off at sea great rafts of them could be seen sitting on the water. Practically all of the birds in this colony were Pallas's Murres. Their eggs were thickly scattered all over the rocks in close rows along the ledges, in every available hollow, nook or crevice big enough to hold an egg and in dense masses, as close as the birds could sit, on the flat spaces and on the sandy slopes. Even at this late date most of the eggs were fresh or nearly so and no young birds were seen.

Toward night, from about 5 p. m. until sunset, the population of the already overcrowded island was still further increased by flocks of Murres constantly coming in from the sea, sometimes in small compact flocks of regular formation but more often in loose straggling parties. Without any apparent cause a cloud of birds would occasionally sweep down from the cliffs, circle about the rocks a few times and then settle down.

STERCORARIUS PARASITICUS

Parasitic Jaeger

Only a few of these birds were seen about the harbors, particularly at Kiska where they were feeding among the gulls. They were in the dark phase of plumage, plain slate gray. On the inland tundra on Kiska Island I saw one of these Jaegers flying about some small ponds where they are fond of alighting and standing for some time on some prominent little hummock, from which a good outlook is obtainable; at such times they are shy and difficult to approach.

RISSA TRIDACTYLA POLLICARIS

Pacific Kittiwake

We saw quite a number of Kittiwakes between Unimak Pass and Unalaska, but as they were all in the distance it was impossible to say whether they were of this or the following species. Elsewhere among the Aleutian Islands they seemed to be very rare or entirely absent.

RISSA BREVIROSTRIS
Red-legged Kittiwake

As we passed Akutan Island we saw a large number of Kittiwakes hovering about the rocky cliffs, which were probably this species, though we could not stop and did not go near enough to identify them. They are listed as breeding on this island. We did not have time to visit their other known breeding grounds.

LARUS HYPERBOREUS
Glaucous Gull

Among the large numbers of Glaucous-winged Gulls seen everywhere, there were undoubtedly a few of this species, perhaps many of them. It was almost impossible to distinguish the slight difference in the wing markings in life and we shot very few gulls for lack of time to prepare them. A few were seen and one was taken at Unalaska.

LARUS GLAUCESCENS
Glaucous-winged Gull

This was the common gull seen on or about all of the islands we visited. They were particularly abundant in the harbor at Unalaska and Dutch Harbor, where they were constantly flocking about the ships to feed on garbage thrown overboard. They were common all the way up the coast from Seattle and in the passes, but seldom seen out of sight of land. I saw a large number of them on the high upland tundra above the cliffs on Kiska Island, where they acted as if they were breeding, but I did not find any nests there. The only breeding colony we found was on Bogoslof Island where there were between one and two hundred nests widely scattered over the flat sandy portions of the island. The nests were well made of kelp and seaweed, decorated with feathers and fish bones. At the time of our visit on July 4, most of the young had hatched and were running about, some nests still contained young or pipped eggs and several held sets of two or three blowable eggs. Wherever these gulls were seen we found numerous shells of sea urchins, far from the water, where the gulls had dropped and broken them to feed on them.

LARUS BRACHYRHYNCHUS
Short-billed Gull

Young birds of this species were common about Ketchikan where we collected a small series. We saw a few adults in Kiska Harbor but did not find their breeding grounds.

DIOMEDEA NIGRIPES

Black-footed Albatross

On the northern Pacific Ocean from Dixon Entrance to Unimak Pass, when two hundred miles or more off shore, a few of these Albatrosses, sometimes as many as six, were almost constantly following the ship, but nearer shore they were seldom seen. We saw a few off the Aleutian Islands both in Bering Sea and the Pacific.

The Short-tailed Albatross, which has been recorded from this region, was not seen.

FULMARUS GLACIALIS GLUPISCHA

Pacific Fulmar

Fulmars were common in the northern Pacific Ocean and Bering Sea, being seen almost constantly about the ship when out of sight of land and frequently closer in. Their graceful movements on the wing were interesting to watch, as they scaled about with their long wings stretched out straight to their fullest extent or flapping rapidly for a few strokes at intervals. Various phases of plumage were noted, light, dark and all grades of intermediates. They breed among the western Aleutian Islands but we did not see their breeding grounds.

FULMARUS RODGERSI

Rodgers's Fulmar

The Fulmars of the northern islands in Bering Sea are supposed to be of this species, but there seems to be some doubt as to the validity of the species and we saw plenty of Fulmars in the Pacific Ocean and about the Aleutian Islands which seemed to be the same as those seen farther north.

PUFFINUS GRISEUS

Sooty Shearwater

PUFFINUS TENUIROSTRIS

Slender-billed Shearwater

Among the vast flocks of dark colored Shearwaters seen in and about Unimak Pass, it was impossible to separate these two species at any great distance. Certainly both species were present, for we identified both at close range, though none were shot as we could not pick them up. I never saw anything approaching their abundance in Unimak Pass when we went through there on June 4; small black whales were numerous and the Shearwaters were following them about to feed on the remnants of food left on the surface by the

whales; on account of this habit they were called "whale birds." The water was literally black with birds all around us as we sailed through acres and acres of them, wildly scrambling to get out of our way or rising in great clouds to sweep away over the smooth water. For several hours we were almost constantly seeing or passing through these great rafts of Shearwaters and I should not dare to hazard a guess as to how many hundred thousand we saw.

The Slender-billed Shearwater is supposed to breed in some of the western Aleutian Islands, but we did not have a chance to investigate.

AESTRELATA FISHERI

Fisher's Petrel

A species of *Aestrelata,* apparently fitting the description of this species, was fairly common in the Pacific Ocean from one hundred to two hundred miles off shore, south of the Alaska Peninsula and the Aleutian Islands, but we were not allowed to lower a boat to secure any. We saw a few also about the Aleutian Islands and secured one specimen at the entrance to Kiska Harbor on June 17. This bird does not exactly fit the description of *fisheri,* and there seems to be some doubt as to whether there is any such species; the three species of *Aestralata* known as *scalaris, gularis* and *fisheri* seem to intergrade more or less and it may yet be proven that all three of these are based on individual variations in a single species and should not be recognized as three different species.

OCEANODROMA FURCATA

Forked-tailed Petrel

This pretty little Petrel was common in the north Pacific Ocean and seen frequently about the Aleutian Islands, breeding on several of them. The only breeding place we found was on Tanaga Island, when they were just beginning to breed on June 25.

Their nests were in burrows in the soft soil at the base of a steep grassy hillside, a mile or so inland. Several burrows were dug out by Mr. Beck, but only one fresh egg was found and only one bird taken.

OCEANODROMA LEUCORHOA

Leach's Petrel

We saw a few in the north Pacific Ocean and a few about the harbor at Kiska where one was shot.

PHALACROCORAX PELAGICUS PELAGICUS

Pelagic Cormorant

This was the common Cormorant of general distribution among the islands. We saw them at every island we visited, but found them nowhere abundant and saw no breeding colonies. They were commonest in Kiska Harbor where we saw them sitting on the rocks in small groups or flying out around our boat; they were probably prompted by curiosity for they usually circled about the boat several times before flying away and were not much alarmed by our shooting. Only a few of them had the nuptial plumage fully developed with conspicuous white flank patches; some had slight traces of white only and many were in the brown immature plumage, probably one year old birds. A Cormorant collected by Mr. Wetmore, at Unalaska on June 8, seems referable to *robustus*.

MERGUS SERRATOR

Red-breasted Merganser

We saw these Mergansers on nearly all of the islands we visited. They were generally distributed throughout the chain, breeding on all suitable islands. We did not find any nests but saw a female with a brood of nine young on Adak Island on June 26.

ANAS PLATYRHYNCHOS

Mallard

Mallards were not common anywhere but we saw a few on Kiska and on Tanaga Islands. On the former a female was seen with a brood of young on June 19. Probably this species breeds sparingly throughout the Aleutian Chain.

NETTION CRECCA

European Teal

NETTION CAROLINENSE

Green-winged Teal

The European bird is supposed to occur only rarely, or as a straggler, in the Aleutian Islands and the American bird is recorded by nearly all of the writers on Aleutian ornithology as the common breeding Teal of the region. Teal of one of these species were common on all of the islands; we saw them frequently and found them breeding in nearly all suitable places along the small water courses and about small ponds. Mr. Wetmore found a nest contain-

ing ten fresh eggs on June 7, near Unalaska and shot the female; unfortunately the male was not secured. We naturally assumed that these were American Green-winged Teal and therefore made no special effort to shoot males on any of the eastern islands, but I now sorely regret that we did not collect at least a few males as the females of the two species are nearly indistinguishable. Among the western and central islands we collected quite a series of both sexes and every male taken proved to be an European Teal; not a single male Green-winged Teal was collected or identified anywhere. On my return to Washington I looked through the National Museum collection for specimens from the Aleutian Islands and found only two males, No. 85615, collected by Lucien M. Turner on Atka Island, June 28, 1879, and No. 192391, collected by Dr. J. Hobart Egbert on Kiska Island, July 14, 1904; both of these proved to be typical European Teal. Therefore, failing to find any positive evidence to prove that the Green-winged Teal breeds on the Aleutian Islands, we must assume for the present, on the strength of what evidence we have, that the European Teal is the common breeding species of this region, where it is fairly abundant, and that the Green-winged Teal, which is so abundant on the main land of Alaska, occurs on the islands rarely, if at all.

MARILA MARILA

Scaup Duck

I saw a flock of five of these ducks in a small pond on Atka Island on June 14. They did not seem to be breeding there or at any other point visited by us.

HARELDA HYEMALIS

Old-squaw

A few were seen on June 11 in Chernofski Harbor on Unalaska Island and at Kiska Island on June 17, but they were not in summer plumage and did not seem to be breeding.

HISTRIONICUS HISTRIONICUS

Harlequin Duck

This is undoubtedly the commonest and one of the most widely distributed of the ducks of the Aleutian Islands. They were seen in large or small flocks at all of the islands where they could find the rocky shores that they love to frequent. They were breeding about the shores of Kiska Harbor on June 17 and probably at other places

we visited, but we did not happen to find any nests. They were frequently seen feeding in pairs about the kelp covered rocks at low tide, among which they were surprisingly inconspicuous and were easily approached.

They were hard to kill however, and would dive readily when shot at or wounded. The unmated pairs were often congregated into large flocks, the adult males generally in flocks by themselves but the flocks of young males or females were usually led by two or three adult males.

SOMATERIA V-NIGRA

Pacific Eider

Eiders were seen about the inner harbors on all of the islands west of Unalaska and in Kiska Harbor they were fairly abundant in small flocks and mated pairs. They frequented the rocky beaches at the bases of the cliffs where they would sit in the loose rocks, feed in the kelp beds about them and build their nests among the large boulders above high water mark. We found two nests here, one with four and one with five fresh eggs, one in a hollow behind the rocks and partially concealed in the long grass, and one in the long grass at the top of a steep grassy slope.

OIDEMIA AMERICANA

Scoter

Flocks of Scoters of both this and the following species were seen on the various islands visited, principally in the harbors, and some of this species were shot at Atka Island on June 14. We saw no evidence of their breeding anywhere and none were seen in any of the inland ponds.

OIDEMIA DEGLANDI

White-Winged Scoter

The same remarks apply to this species, which were easily recognized, but none were shot. They were evidently flocks of non-breeding birds wandering about. I find no record of any Surf Scoters being positively identified among the Aleutian Islands, though we may have seen some.

BRANTA CANADENSIS MINIMA

Cackling Goose

Although we saw a few geese, either this or Hutchins's on Kiska, Adak, Atka and Attu islands, the only one positively identified was one of this subspecies taken by Mr. Beck as she flew from her nest of

four eggs on Attu Island on June 23. If we had had time to thoroughly explore the inland ponds on some of the western islands, where they are said to be common, we should probably have found plenty of geese breeding. The status of these two geese was one of the points we particularly wanted to settle and we were much disappointed at not being able to do so.

LOBIPES LOBATUS

Northern Phalarope

We saw a few Phalaropes on Atka Island where several nests were found with fresh or incomplete sets of eggs on June 18. On Kiska Island they were really abundant and breeding about the small grassy ponds and sloughs, where a set of three fresh eggs was taken on June 21. A small flock of apparently unmated birds of both sexes, in which I counted seventeen birds at one time, frequented the beach almost constantly, swimming about the piers of an old dock or feeding in the surf where they floated buoyantly over the little waves and fluttered over the crests of the small breakers. They were swimming about in little circles, picking up some minute objects from the surface. They were very tame everywhere and, about the ponds where they were breeding, very solicitous and noisy. Their nests were made in little tussocks in the wet meadows around the edges of the ponds or near the banks of streams. They were common on all the other islands where there were suitable breeding grounds.

ARQUATELLA MARITIMA COUESI

Aleutian Sandpiper

The first specimen of this local species was taken on the beach at Akun Island on June 4, and after that we saw them on every one of the islands we visited, but they were not common among the eastern islands. At Tanaga Island they were fairly abundant and breeding on the inland tundra.

Only one nest was found with eggs, on Kiska Island on June 14. While climbing over a high hill a bird fluttered off directly under my feet, on a bare moss covered space where there was only a scanty growth of grass. The four large eggs lay well concealed in a deep little hollow lined with dead leaves and bits of straw. The eggs were only slightly incubated. On Attu Island on June 23, I shot a pair of these birds which were very solicitous and evidently had a nest; after a short search I found it on a little moss covered hummock well up on the hillside; in a hollow similar to the first nest were three beauti-

fully colored downy young, not yet old enough to run. Mr. Wetmore also found a brood of downy young on Adak Island on June 27. We found these sandpipers always very tame and unsuspicious and, except on their breeding grounds, remarkably silent and inactive. They move about very little while feeding and pay no attention to passers-by even at short distances; it was often necessary to back off before shooting one.

On their breeding grounds, on the high dry tundra or mossy hillsides, they were much more active and noisy, indulging in their hovering flight songs thirty or forty feet up in the air, a series of delightful twittering notes as they fluttered downward, or giving their loud musical flute-like whistling notes, suggestive of the melodious calls of the Upland Plover, while flying about or standing on the top of some prominent hummock.

Among a series of eleven birds collected on Attu Island on June 23 are two birds which closely resemble *ptilocnemis* in color, but in size are typical of *couesi*. At least one of them was a breeding bird, the parent of a brood of downy young, and doubtless both of them were summer resident birds. At this point so far west of their normal range and entirely outside of their known migration route, they could hardly be regarded as straggling or belated migrants, which might be expected in the eastern Aleutian Islands. They can, therefore, be regarded only as aberrant specimens of *couesi* or variants towards *ptilocnemis*. In our series of *couesi* from the Aleutian Islands are a number of other specimens which are somewhat intermediate between the two forms but are undoubtedly referable to *couesi*.

LIMOSA LAPPONICA BAUERI

Pacific Godwit

While walking around the shores of a pond on Atka Island on June 13, I flushed two Godwits which I am quite sure were of this species, although I was unable to secure them. They were probably late migrants.

HAEMATOPUS BACHMANI

Black Oyster-catcher

Oyster-catchers were fairly common about Kiska Harbor where we saw them sitting on the rocks or flying about and uttering their loud and penetrating cries. They were remarkably inconspicuous on the rocks and not at all shy. At Adak Island we saw a flock of eight or ten birds several times flying about the harbor or standing on a rocky islet. They may have been breeding at one of these

places but we saw no evidence of it and no, apparently, breeding pairs. They were also noted on Tanaga Island and at Chernofski on Unalaska Island.

LAGOPUS RUPESTRIS NELSONI

Nelson's Ptarmigan

The best known of the Aleutian Ptarmigan inhabits Unalaska Island and Amaknak Island, which are separated only by a narrow channel. About Iliuliuk Village on Unalaska Ptarmigan are scarce and wild, having been persistently hunted by the inhabitants, but across the channel on Amaknak, where most of our birds were taken, we found them common and tame on the steep sloping sides of a mountain locally known as "Ballyhoo." At the time of our visit, June 5 and 9 inclusive, the Ptarmigan were apparently just mating and were scattered all over the sides of the mountain. We found no nests and judging from our experience elsewhere we inferred that they would come down to lower levels to nest in the grassy hollows. A pair of birds could often be located by seeing the song flight of the male, his white wings being quite conspicuous at a great distance as he flies thirty or forty feet upwards and floats or flutters downwards, sometimes scaling on decurrent wings, uttering all the time his loud clucking, rattling call. The male may often be seen sitting on his favorite perch on some prominent hummock where he has a good outlook, but where he is equally conspicuous; he apparently uses the same hummock regularly for it is usually well decorated with dung and feathers. The female is very inconspicuous and moves about very deliberately where she matches her surroundings perfectly.

LAGOPUS RUPESTRIS ATKHENSIS

Turner's Ptarmigan

On Atka Island we found this form of Ptarmigan very abundant; there seemed to be more Ptarmigan here than on any island we visited. There were comparatively few of them on the hillsides, but in the grassy hollows and among the low rolling hills of the valleys we were constantly flushing them. They were apparently mated and breeding on June 13, the day of our arrival, but we failed to find any nests during the next two or three days. The male usually flushed first with loud clucking notes and the female was sure to follow soon after him. They were very tame and we had plenty of opportunities to observe and study their movements, as they conducted

their courtship in the air or strutted about on the ground. The male is a strong flyer and delights in making long scaling flights, particularly against a strong wind when he rises and falls at will on firmly set wings or poises like a falcon over his admiring mate.

LAGOPUS RUPESTRIS TOWNSENDI

Townsend's Ptarmigan

At Kiska Island on June 17, the Ptarmigan of this form were still in the uplands, were much wilder than the Atka birds and not nearly so abundant, but during the few days that we were here we succeeded in collecting a good series. No nests were found; probably we were too early for complete sets.

LAGOPUS RUPESTRIS CHAMBERLAINI

Adak Ptarmigan

The Adak Ptarmigan frequented the high dry tundra and low hillsides where reindeer moss was plentiful as well as the grassy hollows and valleys. They were common but not abundant and we obtained all we needed. Two nests were found, each containing seven nearly fresh eggs. All of these Ptarmigan were feeding entirely on green food, principally the young, green leaves and buds of the dwarf willows, the tops of ground evergreens and mosses and the flower buds and blossoms of herbaceous plants.

LAGOPUS RUPESTRIS SANFORDI

Tanaga Ptarmigan

On Tanaga Island we collected a good series of this bird which proved to be a new subspecies, as elsewhere described.[1] The birds were abundant and tame on the rolling grassy hillocks or sand dunes back of the beach and on the little grassy hills on the tundra. Three sets of eggs were collected and other nests were seen by members of the ships crew, who went hunting on June 25, only a half day being spent on the island. One nest containing nine fresh eggs was in a hollow among some large tufts of grass in the steep bank of a stream. The other nests were in grassy hollows among the hillocks and contained eight fresh eggs each.

LAGOPUS EVERMANNI

Evermann's Ptarmigan

This, the darkest of all the forms, inhabits Attu Island, the western extremity of the chain where it is found on the moss covered and bare, rocky sides of the mountains. It enjoys the rank of a distinct

[1] Smithsonian Misc. Coll., Vol. 56, No. 30.

species, but I doubt if it is correctly so ranked for our material seems to show intergrading with *nelsoni*. We learned less about this than any of the others for our collecting time on this important island was cut down to one cold, rainy, stormy day, when effective collecting was difficult. We collected only one female and seven males. No nests were found, though the female was evidently incubating. What few birds we saw were very tame.

There is much yet to be learned about the relationships of the Aleutian Ptarmigan and their connection with the mainland birds of both continents, but before the subject can be satisfactorily studied, more material must become available from the unexplored islands and the Asiatic mainland. I shall, therefore, have to leave this important matter for future investigation.

HALIÆETUS LEUCOCEPHALUS ALASCANUS

Northern Bald Eagle

Large Bald Eagles were common on all the islands we visited, particularly about Unalaska and Dutch Harbor, where one or more were almost constantly in sight. They were not at all shy, frequently flying within easy gunshot; they were especially bold about their nesting places or near their favorite lookout points on the hilltops, where feathers and droppings indicated that they habitually used the same spot for a perch; at one such spot on the crest of a steep rocky hill, I surprised a large White Headed Eagle which sailed back and forth several times, within a few feet of my head, squealing vigorously all the time as if I were intruding on its home. It undoubtedly breeds on all the islands. Nests with young about half grown or more were found on Atka, Adak, Kiska and Tanaga islands; they were placed on rocky cliffs and some were easily accessible.

Among the numerous dark colored Eagles seen, some were probably Golden Eagles, as the species is recorded as common among these islands. We saw several which we thought might be Gray Sea Eagles, but they did not come near enough to be positively identified.

FALCO PEREGRINUS PEALEI

Peale's Falcon

This species is said to be commoner among the western islands than elsewhere, but we saw large Falcons, undoubtedly this species, on Atka, Kiska, Tanaga and Adak. At Kiska Harbor on Jun 19, I watched a pair of these birds flying about the high rocky cliffs; they were apparently building a nest, as I saw one of them fly up

with a stick in its claws. I also saw a pair mating at Atka Island on June 13. These facts would seem to indicate that they are late breeders. We did not secure any specimens or find any nests.

ASIO FLAMMEUS

Short-eared Owl

A single individual of this species was seen on Amaknak Island, near Dutch Harbor, on June 7, where it was flushed from the top of a small spruce tree, in one of the only two clumps of trees in the Aleutian Islands.

CORVUS CORAX PRINCIPALIS

Northern Raven

Ravens were common throughout the whole Aleutian chain. About Iluliuk Village, Unalaska, they were particularly abundant and absurdly tame. They habitually frequented a steep grassy hillside, across a small creek from the town, whence they made frequent visits to the village. Along the beach and about the houses they were as tame as hens, hopping away a few feet from us or sitting on the fences or on the roofs of the houses like tame Crows. They are useful as scavengers and probably make a good living. Their aerial evolutions are strikingly interesting, showing wonderful command of their flight powers. The young were fully grown and on the wing at the time of our arrival, the first week in June.

HYPOCENTOR RUSTICA

Rustic Bunting

Two specimens of this bird, at that time unknown to us, were picked up dead and partially dried on Kiska Island. On June 19, at the same place, Mr. Wetmore saw and collected a living specimen. I saw two or three birds on Adak Island, which I thought were this species but they were exceedingly shy and I did not collect any. This species occurs regularly in Japan and on the Asiatic mainland from Kamchatka to China, and as a rare straggler only in the Commander Islands.

LEUCOSTICTE GRISEONUCHA

Aleutian Rosy Finch

This characteristic Aleutian species was uniformly distributed in all suitable localities over all of the islands. Its favorite haunts are the rocky mountain sides and summits, its breeding grounds the rocky ravines and inaccessible cliffs and its feeding grounds about

the edges of snow banks on the hillsides and gulches. They are restless, roving birds, sweeping over the mountain tops in long swinging curves, or gathering in small parties on the edges of a melting snow bank to feed on the small insects to be found there, where they are often too shy to approach. About the rocky cliffs and summits, where their nests are well concealed in inaccessible crevices, they are tamest; if one stands still they will come and perch on some near by rock, chirping loudly in protest, or fly about from point to point with their swinging billowy flight, twittering all the time. Mr. Wetmore found a nest on Kiska Island on June 18, containing two fully fledged young; it was in a crevice in the rocks in an almost inaccessible place on the face of a cliff. This was the only nest found.

Rosy Finches were occasionally seen on the rocky beaches, but apparently were only feeding there.

ACANTHIS LINARIA LINARIA

Redpoll

A Redpoll alighted on a spruce tree near Dutch Harbor, on June 7, while I was sitting under it eating my supper, but it flew away before I could grab my gun and I never saw it again. No others were seen.

PLECTROPHENAX NIVALIS TOWNSENDI

Pribilof Snow Bunting

The first Snow Buntings were seen before we had been ashore an hour on Akun Island, and from that time on they were found regularly on all the islands visited, but were nowhere abundant or even common. Though occasionally seen on the beaches or low levels, they were confined almost entirely to the mountain tops and rocky ravines, where they were breeding. They were generally rather shy if we attempted to stalk them in the open but were easily approached among the rocks. The males had a pretty little song and a variety of twittering notes. They were not as active as the Rosy Finches and were generally confined to restricted localities which suited their needs. No nests were found, for we had very little time to devote to small land birds. No young were seen on the wing during June.

CALCARIUS LAPPONICUS ALASCENSIS

Alaska Longspur

Just as the Chestnut-colored Longspur adds a charm to a drive across the inland prairies, so does this beautiful little bird cheer the wanderer over the cold and fog bound tundra of this inhospitable

region by his delightful song and cheerful manner, as standing on the top of some little hummock he whistles in joyful greeting or, flying up into the air, he charms his mate with his melodious flight song. Fortunately these pretty little Longspurs are exceedingly abundant all over the low grassy hills, plains and tundra of all the islands, where they are almost constantly seen and heard; they undoubtedly outnumber all other land birds. They were mating and breeding all through the month of June; nests with fresh eggs were found as early as June 7, and as late as June 27. The nests were placed on the ground, either in or under the tufts of grass or wild rye, usually in grassy hollows in the lowlands, but sometimes on the hillsides or on the tundra. No young birds were seen on the wing during June, but several nests were found with fledged young.

PASSERCULUS SANDWICHENSIS SANDWICHENSIS

Aleutian Savannah Sparrow

This Sparrow was very abundant on Unalaska Island, even as far west as Chernofski, and on the other islands to the eastward of it, but it was not found on any of the islands to the westward of Unalaska. Its favorite haunts were the low, flat, grassy meadows near the beaches and about the ponds and streams, but it was also found more sparingly on the high tundra and low hillsides. In habits and song it closely resembles the eastern Savannah Sparrow. Only one nest was found, by Mr. Wetmore on June 9, containing four fresh eggs.

MELOSPIZA MELODIA SANAKA

Aleutian Song Sparrow

One of the birds peculiar to this region and the most widely variant form of a plastic species is this strikingly large Song Sparrow. Although so widely different from any of the mainland subspecies, it seems to vary very little among the 800 miles of islands forming the Aleutian Chain. Only a few Song Sparrows were seen about the vicinity of Dutch Harbor, but they were very abundant at the western end of Unalaska Island near Chernofski. They were fairly common locally on all of the other islands but nowhere abundant. They were strictly littoral in their habits and were confined almost wholly to the steep grassy banks above the beaches or the rocky and grassy valleys near the shore. In such localities we almost always found at least a few of them breeding. Only one nest was found, at Chernofski on June 10, containing four fresh eggs. It was concealed behind a tuft of grass on a steep grassy bank above the beach. Being a

nearly related small winged bird, the Song Sparrow's flight is slow and direct at all times, the longest flight of the eastern bird. Its song in spite of its many variations, is quite similar to that of its well known eastern relative. The latter I also had a full fall of small migrant

ERIURUS ERYTHROGASTRA

Red-bellied Snake

One was seen at Dutch Harbor on June 5, two more were seen later. I believe it is new to the islands west of Unalaska.

ANTHUS RUBESCENS

Pipit

The species is fairly common on Dutch Harbor and Unalaska islands, arriving and breeding early in June, though I have not found any nests. I did not see them elsewhere among the islands.

PASSER MELANS

Chestnut-backed Bunting

These birds were found on the islands west of Unalaska, but were not common. They frequented the vicinity of the native villages, the only trees of any size in the region. Here were a few loose scattering pairs, but the most beaches among the [illegible] It was surprising to see such a [illegible] the region of such a rugged [illegible] or perching on [illegible] mainly seabirds. [illegible] the [illegible] one of the very few [illegible]

PASSERELLA ILIACA UNALASCHCAE

Townsend Sparrow

[illegible] seem to be a little [illegible]

CALCARIUS LAPPONICUS

Lapland Longspur

[illegible] at Dutch Harbor on [illegible] Westward also [illegible] about some of

This species is abundant in Kamchatka, where it is one of the most attractive birds and an exquisite songster.

Dr. Stejneger records the capture of a single straggler on Bering Island, January 29, 1883; it is therefore a rarity even in the Commander Islands. The capture of our specimen, which is now in the National Museum collection, extends its known range several hundred miles eastward.

III. Birds Noted in Bering Sea in July, 1911

On our return to Unalaska on July 1, we were informed by the Commander of the Bering Sea fleet that the Revenue Cutter Service could do nothing more for us, as they needed the *Tahoma* on the seal island patrol. We therefore made other arrangements for transportation during the remainder of the season. We left Mr. Wetmore at Unalaska to work in that vicinity for a while and to secure passage homeward along the south side of the Alaska peninsula. The results of his work belong to the Biological Survey. The remainder of our party secured passage to Nome on the gasolene schooner *Polar Bear*, owned and commanded by Mr. Louis L. Lane, of Seattle. We sailed from Unalaska on July 3 and reached Nome July 11, having spent one day on Bogoslof volcano, half a day on St. Paul Island, half a day on Walrus and a day at St. Matthew and Hall islands.

No thorough work could be done on such a hurried trip, but we obtained a fairly good impression of the avifauna of these interesting islands and took a large series of photographs. The following notes on the species observed may be worth recording, though I realize that they contain very little new matter.

LUNDA CIRRHATA

Tufted Puffin

A few Tufted Puffins were breeding on Bogoslof Island, making their burrows in the sandy bluffs above the beaches or in the sand and gravel slopes about Castle Rock among the Murres. Their burrows were rather shallow and were generally profusely lined with feathers and straws.

The soft soil on the bare top of Walrus Island was so honeycombed with the burrows of this Puffin that it was difficult to walk without breaking into them; very few Puffins were seen, however, until they were dug out of their burrows when they would go scrambling off towards the water in a frantic effort to fly. They were nesting here also under the loose rocks on the stony beach among the Auklets.

FRATERCULA CORNICULATA
Horned Puffin

A few pairs were seen breeding on the rocky cliffs at St. Paul Island and they were common at St. Matthew Island on the high cliffs among the Fulmars. No nests of this species were examined.

PHALERIS PSITTACULA
Paroquet Auklet

We first saw this large White Breasted Auklet when we approached the shores of St. Paul Island in a dense fog, the direction in which this and other birds were flying helping to locate it. They were nesting in inaccessible crevices in the low rocky cliffs about this island where we saw them sitting in little groups on the rocks or flying out to circle around us. On Walrus Island we found them breeding abundantly, on June 7, where their nests were well hidden under the piles of loose rocks on the beach-like center of the island, in company with the Tufted Puffins, Crested and Least Auklets. The rocks were mostly small so that we did not have much difficulty in moving enough of them to discover the bright white eyes and curious upturned red bills of these Auklets as they sat quietly on their single eggs. The eggs were laid on the bare rocks or soil or on a bed of loose pebbles. They were silent and very gentle as they sat quietly on their nests, quite different in this respect from the other Auklets. On St. Matthew Island we saw a few Paroquet Auklets, apparently breeding, about the tops of the high rocky cliffs, two hundred feet above the sea.

ÆTHIA CRISTATELLA
Crested Auklet

This species was not so abundant as the foregoing, but was breeding commonly on Walrus Island. While hunting for nests among the loose rocks we frequently heard the loud weird cries of this strange bird coming from the innermost recesses of the rocks below us. By moving the rocks we could sometimes see them sitting on their nests. The eggs are similar to those of the Paroquet Auklet, but usually a little smaller and more pointed.

ÆTHIA PUSILLA
Least Auklet

Great clouds of these little birds greeted us on our arrival at St. Paul Island, where they rose from the stony beaches in swarms, and were probably breeding among the loose rocks. Their faint

twittering notes sounded like an immense flock of Peep in full cry or like the distant peeping of countless Hylas.

CEPPHUS COLUMBA

Pigeon Guillemot

A few were seen at St. Paul and Walrus islands, and a few about the high cliffs of St. Matthew Island. They were probably breeding at all of these places, but we spent no time in hunting for their nests.

URIA TROILLE CALIFORNICA

California Murre

Although the Murre colonies at Bogoslof Island were the most extensive I had ever seen and probably included the greatest number of birds, they were totally eclipsed in density by the wonderful colonies on Walrus Island. This is a most remarkable little island, an ornithological wonderland, where ten species of seabirds breed in countless multitudes, far surpassing anything I have ever seen. The California Murres rank first in numbers, literally covering the low cliffs and rocky shores all aound the island, as well as large spaces on top of it, with dense masses of birds sitting remarkably closely. They were exceedingly tame or stupid and would allow a near approach, but if hard pressed they would rise on their toes and waddle off, flapping their wings rapidly; the clatter of many hundred pairs of wings increasing to a deafening roar, they would pour off in streams, stumbling over each other as they scrambled down to the water, pattering over its surface to join the distant rafts of Murres on the water or diving straight downward and flying away rapidly below the surface. Plenty of Murres, mostly of this species, were breeding on the perpendicular cliffs of St. Matthew Island.

URIA LOMVIA ARRA

Pallas's Murre

Among the vast hosts of California Murres on Walrus Island were a few of this species. On the cliffs of St. Paul Island this species was breeding among the Puffins and Kittiwakes. At St. Matthew Island a few Pallas's Murres were seen, although they were far outnumbered by the foregoing species. All through Bering Sea Pallas's Murres were frequently seen flying about, even out of sight of land, in small flocks or singly.

RISSA TRIDACTYLA POLLICARIS

Pacific Kittiwake

This seems to be the commonest gull in Bering Sea. We saw a few breeding on the cliffs at St. Paul Island; they were quite common on Walrus Island and a few were nesting on the high cliffs on St. Matthew Island. At Walrus Island, where there are no high cliffs, we had an unusually good opportunity to examine their nests, which were placed on little shelves on the faces of perpendicular rocks in little groups of from four to six pairs each, often close to the Murres or Red-faced Cormorants. The nests were neatly made of soft green grasses, securely plastered onto the rocks, and contained one or two eggs.

RISSA BREVIROSTRIS

Red-legged Kittiwake

Only one specimen of this beautiful species was taken, between Bogoslof and the Pribilof islands. Several were seen about the latter and could be distinguished by their darker mantles, short bills, less black on their wing tips and by their bright red feet. We did not see their breeding grounds.

LARUS HYPERBOREUS

Glaucous Gull

In the large breeding colony of Gulls on Walrus Island there were certainly a number of Glaucous Gulls, but just what the proportions were of this and the following species we were unable to determine as we were not allowed to do any shooting here. Only a few nests still contained eggs, as most of the young Gulls were running about and hiding under the tufts of grass which covered the highest part of the island.

LARUS GLAUCESCENS

Glaucous-winged Gull

I assumed that the majority of the Gulls breeding on Walrus Island were of this species, but I have no reason for the assumption except that this seems to be the commoner species. It is to be regretted that we were unable to shoot any, although photography gave us plenty to do during the half day spent on this fascinating little island.

STERNA PARADISÆA

Arctic Tern

A few Terns were seen in the northeastern part of Bering Sea, undoubtedly of this species, which was the bird found at Nome.

FULMARUS RODGERSI

Rodgers's Fulmar

The Fulmars of the northern islands of Bering Sea are supposed to be of this species while those about the Aleutian Islands are supposed to be the Pacific Fulmar. There is so much individual variation in Fulmars that the careful study of a very large series is necessary to determine satisfactorily the validity of this species and I doubt whether the characters of *rodgersi* would prove sufficiently constant to warrant its recognition as a distinct species. I saw Fulmars on the Pacific Ocean which certainly looked like *rodgersi* and about the high cliffs of St. Matthew Island, where Rodgers's Fulmars were breeding in large numbers, I could see from an advantageous point on the top of the cliff, where I could look down upon their backs, a great variety of color patterns on the birds circling below me. It would be well worth while to collect a large series of them here and thus determine the constancy of the specific characters. This was the only breeding colony of Fulmars that we saw; they were breeding in large numbers all over the faces of several high, precipitous, rocky cliffs where the eggs were laid on narrow ledges entirely inaccessible so far as we could see; but an hour or two on shore with a camera was hardly time enough for thorough exploration. The Fulmars were not shy and were constantly flying in and out or conducting their courtships on the narrow ledges below me.

PHALACROCORAX URILE

Red-faced Cormorant

Among all the birds breeding in the large colonies of Walrus Island, these beautiful and rare Cormorants interested me most, for I had never seen the species alive before and there are very few places where it can be seen, as it is restricted to Bering Sea, where it is constantly resident. There was not a large number of them, perhaps fifty or one hundred pairs, scattered over the island in small groups, nesting on the broader level ledges on the outer and higher rocks. The nests were rather prettily made of various kinds of seaweeds, kelp, sea mosses and green grass, not very large and rather clean for Cormorants' nests. Most of the nests contained three or four young of various ages, naked and blind at first, but afterwards covered with soft gray down mixed with white on the belly. The birds were exceedingly tame as they stood beside the nests brooding over their young, allowing us to walk up and photograph them within a few feet. The beautiful metallic colors of their plumage, purple, blue, green and

bronze, their bright scarlet faces and gular pouches of rich smalt blue, made a strikingly handsome combination, as they stood craning their necks at us in ignorant stupidity as if they had never seen a man before. They were generally silent, but occasionally uttered a loud, rolling gutteral croak, when alarmed. A few of the nests still contained, on July 7, three or four eggs. One nest contained two eggs of the Cormorant and a Murres egg, which may have rolled into it from the rocks above.

HARELDA HYEMALIS

Old-squaw

Two pairs of Old-squaws in summer plumage were seen in a small pond near the village on St. Paul Island, where they were probably breeding.

PHALAROPUS FULICARIUS

Red Phalarope

A few flocks of large light-colored Phalaropes were seen flying over the northern parts of Bering Sea and one, a beautiful adult bird, came near enough to be identified.

ARQUATELLA MARITIMA PTILOCNEMIS

Pribilof Sandpiper

These Sandpipers were common on the low tundra at the south end of St. Matthew Island, in the interior at the north end and on Hall Island. Several specimens were taken by Mr. Kleinschmidt.

HETERACTITIS INCANUS

Wandering Tattler

A single bird of this species was heard on the rocky beach of St. Paul Island, near the fur-seal rookeries, on July 6.

LEUCOSTICTE GRISEONUCHA

Aleutian Rosy Finch

A few were seen on St. Paul Island about the rocky places near the killing grounds.

PLECTROPHENAX HYPERBOREUS

McKay's Snow Bunting

The name *hyperboreus* well fits this snow white bit of Arctic bird life which we saw sweeping down in long, curving flights from the rocky hills of St. Matthew Island to feed around the edges of the

snow glaciers in the valley. The male is almost wholly white and is a strikingly conspicuous bird as it flits about the rocks of its summer home. A pair were taken on this island and several on Hall Island. One nest was found containing young nearly fledged in an almost inaccessible crevice in the face of a rocky cliff, on July 9.

CALCARIUS LAPPONICUS ALASCENSIS

Alaska Longspur

They were fairly common on St. Paul Island on the grassy plains about the killing grounds.

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 56, NUMBER 33

THREE NEW PLANTS FROM ALBERTA

BY

PAUL C. STANDLEY

(PUBLICATION 2069)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
FEBRUARY 7, 1912

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

THREE NEW PLANTS FROM ALBERTA[1]

By PAUL C. STANDLEY

During the summer of 1911 Mr. N. Hollister and Mr. J. H. Riley made an extended reconnaissance of the animal life of the mountains of eastern British Columbia and western Alberta.[1] At the same time they secured representatives of many of the plants of this little explored region, their collections consisting of over two hundred numbers. Coming from a territory where little or no botanical collecting had been done previously, these have proved to be of more than passing interest. In the course of identifying the plants secured by the two collectors three were found which seem to be undescribed. It is expected later to publish an annotated list of the species represented in the series of specimens, but it seems advisable to publish here the descriptions of the new ones in advance of the complete report.

VAGNERA PUMILA Standley, sp. nov.

Low perennial 10 cm. high or less; leaves few, usually only 2, with one or 2 very small bract-like leaves just below the inflorescence, elliptic or elliptic-oval, 20 to 50 mm. long and 8 to 14 mm. wide, abruptly acute, sessile by a clasping base, finely parallel-veined, glabrous; inflorescence a stout raceme about 5 cm. long, well exserted beyond the leaves, the flowers rather widely spaced; pedicels stout, ascending, 6 to 8 mm. long, glabrous, subtended by minute, scarious, obtuse, purple-dotted bracts; perianth segments 3 mm. long, oblong, obtuse, white conspicuously blotched with purple; filaments stout, slightly thickened towards the base; anthers purple; stigma very short and thick, not longer than wide, the styles often nearly sessile; mature fruit not seen.

Type in the U. S. National Herbarium, no 622636, collected on Prairie Creek, western Alberta, July 3, 1911, by J. H. Riley (no. 100).

[1] Some new species of birds collected by this expedition are described by J. H. Riley in Proc. Biol. Soc. Washington, Vol. 24, pp. 233-236, 1911; and four new mammals are described by N. Hollister in Smithsonian Misc. Coll., Vol. 56, No. 26, December 5, 1911.

This is a distinct species related to *V. trifolia* which occurs farther east in Canada and has been reported from the western mountains. The writer has seen no other western specimens so cannot determine whether the other material referred to *V. trifolia* is of that species or rather belongs here. *Vagnera pumila* is distinguished from the eastern plant by the short leaves, small size of the plant, less spreading pedicels, and especially by the very short style. The raceme, too, is all exserted beyond the leaves while in *V. trifolia* it seldom more than equals them.

ARTEMISIA LAEVIGATA Standley, sp. nov.

Perennial; stems stout, 25 to 30 cm. high, erect from an ascending base, finely striate, reddish, glabrous; basal leaves on slender petioles, twice pinnatifid into oblong-linear acute segments, glabrous, bright green, thick; cauline leaves mostly once, sometimes twice pinnatifid into narrow acute segments, the upper ones sessile, the lower petiolate, those of the inflorescence mostly oblong-linear and entire; heads few, about 5 to 8, large, 8 to 10 mm. in diameter, broadly campanulate, cernuous on slender erect peduncles 7 to 16 mm. long; bracts glabrous, 3 to 4 mm. long, in 2 or 3 series, ovate, obtuse, with scarious erose margins, green with a broad dark brown border; receptacle naked, glabrous; flowers apparently all fertile; corolla trumpet-shaped, slightly constricted at the throat, 2 mm. long, with short-triangular erect or reflexed lobes, glabrous or with a few short white hairs at the base, yellowish or the lobes tinged with reddish purple; mature achenes not seen, the undeveloped ones short, glabrous.

Type in the U. S. National Herbarium, no. 622563, collected at the head of Smoky River in western Alberta, August 5, 1911, by J. H. Riley (no. 30).

This appears to be most closely related to *Artemisia arctica* Less. It differs from that species and its allies in being quite glabrous. Its leaves, too, are less dissected than in other members of the group.

GAILLARDIA BRACTEOSA Standley, sp. nov.

Stems rather slender, tall, about 70 cm. high, ascending or erect, branched from the base and throughout, sparingly and minutely glandular, beset with abundant cobwebby hairs, purplish, striate; basal leaves not seen; cauline ones lanceolate or oblong lanceolate, 35 to 80 mm. long and 10 to 18 mm. wide, entire, acute or nearly obtuse, sessile by a usually clasping base, bright green, minutely

glandular-puberulent and with rather few soft, weak, many-celled hairs on both surfaces; peduncles long and tortuous, 14 to 22 cm., glandular-puberulent and abundantly villous; heads, exclusive of the rays, 2 cm. in diameter, hemispheric or nearly globose; involucral bracts in several series, 1 to 2 cm. long, elliptic or elliptic-lanceolate, the outer much longer and broader than the linear inner ones, purplish at the base and on the margins, elsewhere bright green, most of them abruptly acute, freely arachnoid especially when young; rays bright deep yellow, 25 to 30 mm. long, 3-lobed at the apex, the lobes oblong, obtuse, glabrous on the upper surface but bearing a few short, several-celled hairs beneath; corollas purplish, the tube nearly or quite glabrous, the lobes triangular, acute, glandular-villous; achenes obpyramidal, densely covered with coarse, appressed, bristle-like hairs; pappus of lanceolate, white, hyaline scales with long-attenuate tips; fimbrillæ of the receptacle coarse, setiform, not much longer than the achenes.

Type in the U. S. National Herbarium, no. 622536, collected near Henry House, Alberta, September 11, 1911, by J. H. Riley (no. 4).

Our plant, the northernmost representative of the genus apparently, is similar to *G. aristata* Pursh but is at once distinguished by the elongated, broad outer bracts of the involucre as well as by the tall stems, short fimbrillæ of the receptacle, entire leaves, and rather different pubescence.

SVIDA PUBESCENS (Nutt.)

Cornus pubescens Nutt. Sylva 3: 54. 1849.
Cornus sericea ? occidentalis Torr. & Gr. Fl. N. Amer. 1: 652. 1840.
Cornus occidentalis Coville, Contr. Nat. Herb. 4: 117. 1893.

Among the shrubs collected is one which appears not to have been segregated from the genus with which it has been associated. As has been shown by Dr. J. K. Small and others, the genus Svida is a well marked one, and should not be combined with typical Cornus.

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 56, NUMBER 34

A NEW LEATHER FLOWER FROM ILLINOIS

WITH ONE PLATE

BY

PAUL C. STANDLEY

(PUBLICATION 2070)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
FEBRUARY 7, 1912

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

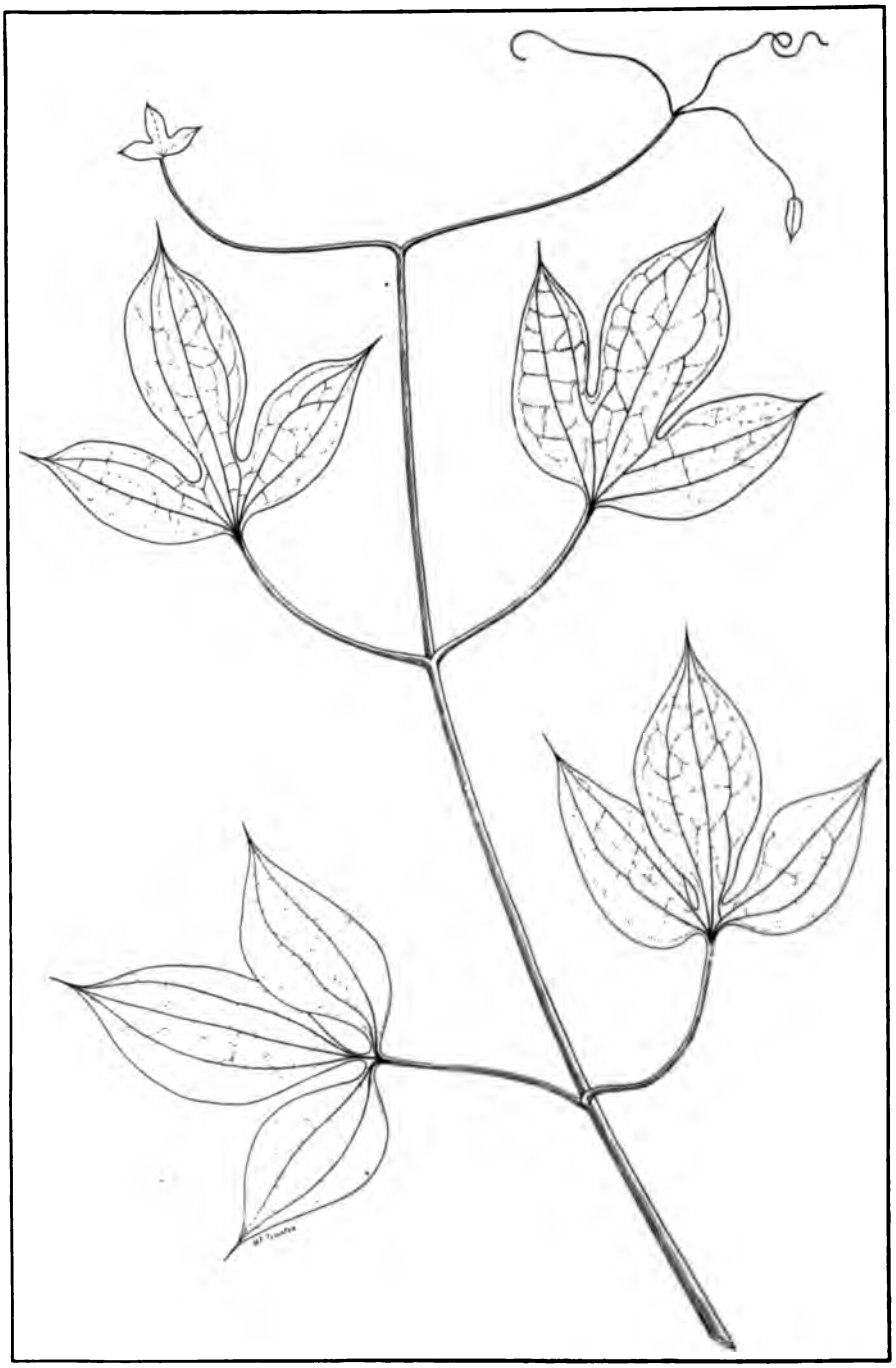
A NEW LEATHER FLOWER FROM ILLINOIS.

By PAUL C. STANDLEY

(With One Plate)

During the last three or four years Mr. Robert Ridgway, Curator of the Division of Birds of the U. S. National Museum, has presented to the National Herbarium several interesting lots of plants collected at his summer home, Bird Haven, near Olney, Richland County, in southern Illinois. Coming from a region of whose flora we know comparatively little, either through published reports or through herbarium material, these collections have proved to be especially interesting and might well be reported upon fully.

Bird Haven consists of some eighteen acres situated two and one-half miles north of Olney. The land was once entirely cleared and many of the original components of its flora have doubtless disappeared. In later years the ground has remained untilled and unpastured and is now covered with a growth of trees and shrubs, while many of the herbaceous plants have reestablished themselves. Although some of the arborescent species are represented only by still immature individuals no less than 56 have been detected within this small area. As examples of the interesting variety of trees and shrubs growing spontaneously here may be enumerated the following: *Juniperus virginiana, Salix nigra, Populus deltoides, Quercus imbricaria, Q. schneckii, Q. palustris, Q. macrocarpa, Q. platanoides, Q. rubra, Q. velutina, Q. marilandica, Q. minor* and *Q. acuminata; Juglans nigra* and *J. cinerea; Hicoria minima, H. alba, H. glabra, H. villosa, H. laciniosa,* and *H. ovata; Ulmus fulva* and *U. americana; Morus rubra, Celtis crassifolia, Toxylon pomiferum, Asimina triloba, Liriodendron tulipiferum, Platanus accidentalis; Malus angustifolia* and *M. coronaria; Prunus americana* ?, *P. hortulana, P. angustifolia* ?, and *P. serotina;* two species of Cratægus, *Gleditsia triacanthos, Cercis canadensis; Acer saccharum, A. rubrum* and *A. nigrum* ?; Sassafras, two species—perhaps three—of Fraxinus; *Nyssa sylvatica, Cornus florida, Diospyros virginiana, Catalpa catalpa,* and *Viburnum prunifolium.* Liquidambar grows near by, as well as *Quercus michauxii.* Along the Big Fox not far distant are found *Ulmus*



VIORNA RIDGWAYI Standley
(TWO-THIRDS NATURAL SIZE)

SMITHSONIAN MISCELLANEOUS COLLECTIONS

VOLUME 56, NUMBER 35

NEW MAMMALS FROM CANADA, ALASKA, AND KAMCHATKA

With Three Plates

BY

N. HOLLISTER

(Publication 2072)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
FEBRUARY 7, 1912

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

NEW MAMMALS FROM CANADA, ALASKA, AND KAMCHATKA

By N. HOLLISTER

(With Three Plates)

A study of the larger mammals collected by the Smithsonian party on the Alpine Club of Canada expedition to Jasper Park and the Mount Robson region, during the summer of 1911, has resulted in the discovery of several unrecognized forms. The hoary marmot and the caribou from the vicinity of Moose Pass prove to be new; and a thorough study of the caribou in the National Museum collections shows the necessity of recognizing three additional forms. For the subspecies of the eastern woodland caribou found in Keewatin and Manitoba, Richardson's name *sylvestris* is revived; and new species from the Arctic coast of Alaska and from Kamchatka are named.

MARMOTA SIBILA, sp. nov.

Type from head of Moose Pass branch of the Smoky River, Alberta; 7,200 feet. Cat. no. 174503, U. S. National Museum. Adult female, skin and skull. Collected August 3, 1911, by N. Hollister and C. D. Walcott, Jr. Original no. 3871.

Characters.—A large member of the *caligata* group; much larger (as known only by the female) than *M. caligata;* coloration dark; cheeks ochraceous. Skulls of females equal in size to largest male skulls of *caligata.*

Color of type (new coat replacing the worn pelage).—Hair around nose and lips white; top of nose and malar stripe black; a whitish strip across forehead between eyes; top of head and nape mixed brown and black; sides of neck and lower throat ochraceous. Shoulders and forward part of body, above, grizzled, the hairs dull blackish underneath, white above, with brownish-black tips. Posterior part of back (still largely in the old coat) mixed brown, black, and buff. Feet black, the hands with scattering white hairs. Underparts brownish-gray, bright hazel at base of tail. Tail above with black center; bordered and tipped with dull mummy brown; beneath Vandyke brown. Immature specimens differ from young of *M. caligata,*

from western Alaska, in the great amount of black in the coat. Two young males have the whole crown, nape, lower back, and feet, black; and the tail black above and below, narrowly edged with ochraceous.

Skull and teeth.—The skulls of females are slightly larger than male skulls of *M. caligata,* and are about the size of male skulls of *M. olympus.* Compared with skulls of adult females of *caligata,* the female skulls of *M. sibila* are very much larger, relatively narrower, and with elongated rostra. The orbital ring is relatively much smaller; the tip of postorbital process, as viewed from above, almost in center between maxillary and squamosal arms of zygomatic arch [in *caligata* much further back, or forward only about one-third the distance from squamosal arm]; coronoid process of mandible reduced, the superior notch one and one-half times as long as high at point of coronoid process [in *caligata* same length as height to point of coronoid]; teeth slightly smaller.

Measurements of type (adult female).—Head and body, 510 millimeters; tail vertebræ, 210; hind foot, 95. Skull of type and female topotype, the latter in parentheses: Condylobasal length, 101.5 (104.2); palatal length, 56.5 (62.1); postpalatal length, 40.9 (38.5); zygomatic breadth, 67 (66.3); length of nasals, 44 (40.5); alveolar length of upper tooth row, 22.5 (23.5); alveolar length of mandibular tooth row, 21 (22.3).

Remarks.—A large series of hoary marmot skulls from the Alaska Peninsula around the coast to Mount Rainier, Washington, including topotypes of *M. vigilis,* shows remarkably little variation in size; and the relative size of male and female skulls is constant. The males are considerably larger. As the female skulls of *M. sibila* about equal the male skulls of *M. olympus,* the new species must be the largest American marmot. Specimens of the hoary marmot from Stuart Lake, Barkerville, Glacier, and other points in British Columbia, west of the main Rockies, and from northern Idaho, are much like true *caligata* from western Alaska, and show no approach toward *M. sibila* in cranial characters. The name *Arctomys okanaganus,* proposed by King in 1836[1] for a hoary marmot from the southern interior of British Columbia thus remains in synonymy, unless the *caligata*-like marmots of these interior ranges prove subspecifically separable from true *caligata* from Bristol Bay. A female specimen

[1] Narrative of a Journey to the Arctic Ocean, Vol. 2, p. 236, 1836.

from St. Mary's Lake, Montana, is clearly referable to *M. sibila,* which thus ranges along the eastern Rockies to the United States boundary.

RANGIFER FORTIDENS, sp. nov.

Type from head of Moose Pass branch of the Smoky River, Alberta (north-east of Mount Robson). Cat. no. 174505, U. S. National Museum. Adult male, skin and skull. Collected July 29, 1911, by. N. Hollister and C. D. Walcott, Jr. Original no. 3826.

Characters.—Largest of the caribou, exceeding in measurements the largest specimens of *Rangifer osborni* and *R. montanus.* Coloration very dark, no whitish on underparts of body. Teeth conspicuously larger than in other species. Antlers stout and heavily palmated; not so long and slender as in *osborni;* main beam nearly straight. Females normally without antlers.

Color of type.—Head blackish-brown; neck grayish-brown, with a small white throat-mane. Shoulders and body deep brownish-black; a stripe of the old pelage on belly shows the long faded brown hair of the winter coat; the new coat coming in here is almost as dark as the back. Legs blackish-brown; feet broadly white around hoofs. Rump patch small, white; tail like back above, bordered with white, a continuation of the rump patch. Five topotypes, four younger bulls and one cow, show the new coat, which is replacing the faded winter pelage, to vary from clove brown to clear black .

Skull and teeth.—Skull largest in size, general proportions much as in *osborni,* but larger, more massive, and with rostrum and palate actually and relatively much broader, and nasals proportionally longer. Exceeds the largest skulls of *montanus* from the Selkirk and Gold Ranges in every measurement. Teeth conspicuously larger than in any other species; each tooth longer and much heavier. Upper premolars and the mandibular teeth especially large. Posterior external cusp of pm_3 and pm_4 separated from remainder of crown-pattern of respective teeth by a deep and broad valley, widening at the exterior edge; the cusp ridge standing almost at right angles with longitudinal axis of tooth, the crown-pattern connecting with tooth immediately behind rather than pattern of crown of tooth of which it is a part. Compared with corresponding teeth of other caribou this character is very conspicuous. In the last premolars of other species, the posterior external cusp lies close to and parallel with the diagonal ridge connecting the posterior internal cusp with the main outer cusp, from which it is separated by a narrow and shallow sulcus. Incisors of the " woodland " type

(more uniformly grading in size from middle to outer pair than in the "barren-ground" type, which decrease by conspicuous steps, with the outer pairs very small).

Antlers large and stout; main ascending beam rather straight, without the low, sweeping, backward curve of *osborni;* less slender and more palmated.

Measurements of type.—Head and body, 2,220 millimeters; tail vertebræ, 150; hind foot, 690. Skull: Condylobasal length, 427; palatal length, 268; postpalatal length, 136.5; greatest orbital breadth, 182; greatest length of nasals, 151; maxillary tooth row, crowns, 112; mandibular tooth row, crowns, 120; length of upper molars, 62.1; upper premolars, 52; greatest breadth of m^3, 18; lower molars, length, crowns, 70.5; lower premolar row, 50.

Remarks.—From its large size and dark coloration, this species scarcely needs comparison with *Rangifer caribou sylvestris* Richardson, represented in the National Museum collection by specimens from Nelson River, Keewatin, and east of Lake Winnipeg, Manitoba. Six specimens of *Rangifer fortidens,* all from the type locality, have been examined. Apparently the females of this species are normally without antlers. A number seen and one killed lacked them, and the resident hunters all told me this was the usual condition. The cow collected, a sub-adult specimen, has small knobs on the skull, which did not pierce the skin. The type specimen, a magnificent bull, was shot by Chas. D. Walcott, Jr., in the snow fields above timberline.

RANGIFER CARIBOU SYLVESTRIS (Richardson)

1829. *Cervus tarandus,* var. *β sylvestris* Richardson, Fauna Boreali-Americana, Vol. 1, p. 250.

Type locality.—Southwestern shores of Hudson Bay.

Characters.—Like *Rangifer caribou caribou* of eastern Canada, but skull longer and more slender; rostrum narrower; teeth larger, the tooth rows, especially mandibular row, longer; nasal bones longer. Neck and head darker in color; ears, back and sides of neck, much darker, the hairs brown to roots.

Measurements of skulls.—Adult male (east of Lake Winnipeg, Manitoba): Total length 417 millimeters; condylobasal length, 398; greatest orbital breadth, 163; breadth of rostrum in front of first premolars, 73; upper tooth row, 107; lower tooth row, 112.5. Adult female (Nelson River, Keewatin): Total length, 396; condylobasal length, 377; greatest orbital breadth, 165.5; breadth of rostrum in front of first premolars, 68; upper tooth row, 102.5; lower tooth row, 113.5.

Remarks.—A careful comparison of four skulls of adult caribou from Manitoba and Keewatin with ten skulls from eastern Canada and Maine, has convinced me that Richardson's *sylvestris* is a good subspecies of the eastern *Rangifer caribou*. I am indebted to Dr. Glover M. Allen, of the Museum of Comparative Zoölogy, Cambridge, Massachusetts, for the loan of several skulls of eastern caribou, to supplement the National Museum series for this study.

RANGIFER EXCELSIFRONS, sp. nov.

Type from Meade River, near Point Barrow, Alaska. Cat. no. 16755, U. S. National Museum. Adult male, skull only. Collected March, 1883, by Lieutenant P. H. Ray. Original no. 1496.

Characters.—Skull short and broad. Compared with a large series of skulls of *Rangifer arcticus* from Fort Anderson and Fort Rae, Mackenzie, it is about the same average breadth across orbits, but with rostrum considerably shorter. Braincase very high; the frontal bone abruptly rising, back of frontal depression, to a height of 35 millimeters above general plane of rostrum; angle of profile of forehead from line of nasal bones and anterior portion of frontals is about 45 degrees. The two branches of the parieto-frontal suture meet to form the median frontal suture at the apex of this high crown. Hollow between orbits deep and rounded. Teeth much as in *arcticus*. Compared with all American mainland caribou the character of this high braincase is very distinctive. The skull of *Rangifer grælandicus*, however, exhibits much the same forehead inflation, but the braincase in this species is very narrow, as opposed to the broad braincase of *R. excelsifrons*. The general shape of the skull of *excelsifrons* is much like that of the Kamchatkan reindeer but the size is very much less.

Measurements of type skull.—Condylobasal length, 366 millimeters; basal length, 344; palatal length, 230; postpalatal length, 114; greatest breadth, 175; greatest length of nasals, 119; maxillary tooth row, crowns, 92.5; mandibular tooth row, 96; upper molars, 52; upper premolars, 43; lower molars, 57.1; lower premolars, 42.

Remarks.—With a series of over eighty skulls of American mainland caribou before me, I find no specimens of other forms approaching *R. excelsifrons* in the peculiar shape of the braincase. Compared with a good series of skulls of *R. stonei*, the skull of *R. excelsifrons* is very short and relatively broad. Skulls of old male *stonei* frequently develop a longitudinal ridge on the forehead, which is very different from the general broad elevation of the crown of *excelsi-*

frons. The two skulls of *R. granti* available for comparison are peculiar in the hypsodont character of the molariform teeth. Two skulls, collected by Lieutenant Ray on the Meade River, are referred to this new species. Unfortunately no skins of caribou from the Arctic coast of Alaska are available, and the external characters of this form can not now be described.

RANGIFER PHYLARCHUS, sp. nov.

Type from southeastern Kamchatka. Cat. no. 21343, U. S. National Museum. Adult male, skull. Collected in 1883, by Dr. Leonhard Stejneger. Orig. no. 2709.

Characters.—Largest of the Palearctic reindeer; exceeds *Rangifer tarandus fennicus* of Finland in every important cranial measurement. Skull very much larger than that of *R. t. sibiricus*, with higher braincase and smaller teeth.

Skull and teeth.—Skull large, massive, and elongated. Compared with measurements of skull of *R. t. sibiricus*, as published by Doctor Lönnberg,[2] it is very much larger than that form, with a relatively narrower rostrum. Braincase high and rounded; frontal bones concave in center and rising abruptly, back of frontal depression, to a height of about 35 millimeters above plane of rostrum. Lachrymal vacuities large. Mandible relatively slender. Tooth rows measuring less than in *sibiricus*, but probably averaging about same actual size, and thus relatively much smaller. The incisor teeth are, unfortunately, missing.

Measurements.—For measurements of the type skull see table below.

Remarks.—As known from the skull alone, the Kamchatkan reindeer is a very different animal from the species of northeastern Siberia, referred by Doctor Lönnberg to *R. t. sibiricus* Murray. The name *sibiricus* dates, however, from Schreber, "Die Saugthiere," plate 248c, 1784, instead of from Murray's "Geographical Distribution of Mammals," as stated by Doctor Lönnberg. This fact puts the question of the name of the reindeer from the Chukchi country, as represented by the Nordqvist specimen described by Doctor Lönnberg, in a different light. A careful review of the text for the reindeer plates of Schreber's work, published in 1804, gives little help in determining a type locality for *sibiricus*. It is evident that the plate is chiefly based upon a description of the color of the 'Siberian' reindeer, furnished Schreber in a letter from Pallas—"Die sibiris-

[2] Arkiv för Zool., Vol. 6, hft. 1, No. 4, pp. 17-18, 1909.

chen sind nach Pallas im Sommer dunkel mausefarbig, im Winter weisslichgrau," (Schreber, l. c., p. 1034). On page 1039, Schreber says that Pallas found wild reindeer on the Kama and Ufa; and on the Obi, in the neighborhood of the Berezov Mountains. The last place, as a Pallas Siberian locality known at the time to Schreber, might be regarded as the type locality.

From our present imperfect knowledge of the Asiatic wild reindeer, it has been necessary for me to compare the Kamchatkan animal with Doctor Lönnberg's '*sibiricus*' of the Chukchi country, though it is scarcely to be doubted that there is more than the one form of this animal between the extremes of northeastern and northwestern Asia. The size and relative proportions of the Kamchatkan species are best expressed in a table of comparative measurements. In the following I have copied Doctor Lönnberg's measurements of adult male skulls of *R. t. fennicus* and of *R. t. 'sibiricus,'* and added the measurements of the type skull of the new species from Kamchatka.

Measurements of Skulls of Adult Male Reindeer.	*R. t. fennicus*	*R. t. 'sibiricus'*	*R. phylarchus*
Basal length	357	329	387
Distance from *crista occipitalis* to tip of premaxillaries	397	362	430
Distance from *crista occipitalis* to tip of nasals	302	276	325
Length of nasals	125	129	135
Width of single nasal at *os supramaxillare accessorium*	21	16	23.4
Width of single nasal at middle	23.5	18	25
Width of single nasal just in front of lachrymal vacuity	36	37	43.6
Combined width of both nasals at *os supramaxillare accessorium*	36	32	40.2
Combined width of both nasals at narrowest place	33	29	39.5
Combined width of both nasals just in front of lachrymal vacuities	54	62	68
Distance from *crista occipitalis* to posterior end of nasals	176	147	195
Distance between tip of nasals and tips of premaxillaries	104	92	119.5
Distance in line from m^2 to nasal suture	115	103	120
Vertical height of skull on level with anterior end of nasals	69	57	74
Width of skull just behind the canines	69	72	75
Width of skull on a line with anterior end of nasals	72	69	72
Interorbital width at the middle of the orbits	149	126	148
Width of skull on a level with *meatus auditorius*	142.5	117	153.2
Zygomatic width just behind the orbits	149	139	152
Length of upper molar series	85	93	91.5
Length of lower molar series	90	102	98.5
Distance from orbit to tip of premaxillary	243	223	268

EXPLANATION OF PLATES.

PLATE 1

Molar-premolar Rows of *Rangifer* (Natural Size)

FIG. 1 *R. fortidens*, upper left tooth row. Type. ♂ ad. Smoky River, Alberta. (Cat. No. 174505 U. S. N. M.)

FIG. 1a. *R. fortidens*, lower left tooth row. Type.. ♂ ad. Smoky River, Alberta. (Cat. No. 174505 U. S. N. M.)

FIG. 2. *R. osborni*, upper left tooth row. ♂ ad. Klappan River, British Columbia. (Cat. No. 171093 U. S. N. M., Biological Survey Collection.)

FIG. 2a. *R. osborni*, lower left tooth row. ♂ ad. Iskut River, British Columbia. (Cat. No. 171092 U. S. N. M., Biological Survey Collection.)

FIG. 3. *R. montanus*, upper left tooth row. ♂ ad. Okanagan County, Washington. (Cat. No. 105947 U. S. N. M.)

PLATE 2

Skulls of *Rangifer* (ventral views, reduced)

FIG. 1. *R. caribou caribou*. ♀ ad. Houlton, Maine. (Cat. No. 57823, U. S. N. M.)

FIG. 2. *R. caribou sylvestris*. ♀ ad. Nelson River, Keewatin. (Cat. No. 3289, U. S. N. M.)

FIG. 3. *R. phylarchus*. ♂ ad. Type. Eastern Kamchatka. (Cat. No. 21343, U. S. N. M.)

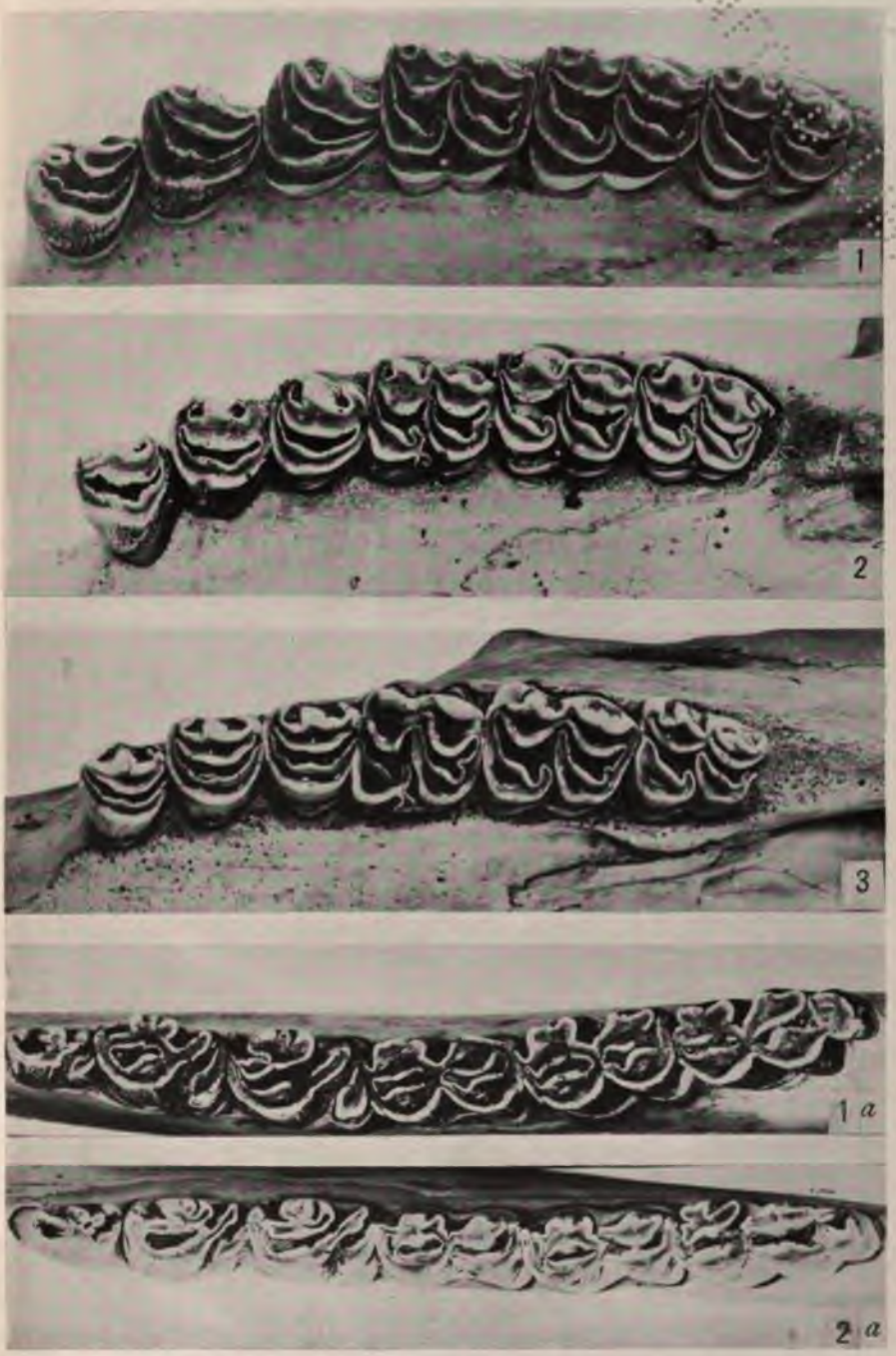
PLATE 3

Skulls of *Rangifer* (lateral views, reduced)

FIG. 1. *R. excelsifrons*. ♂ ad. Type. Meade River, Alaska. (Cat. No. 16755, U. S. N. M.)

FIG. 2. *R. arcticus*. ♂ ad. Fort Rae, Mackenzie. (Cat. No. 6277, U. S. N. M.)

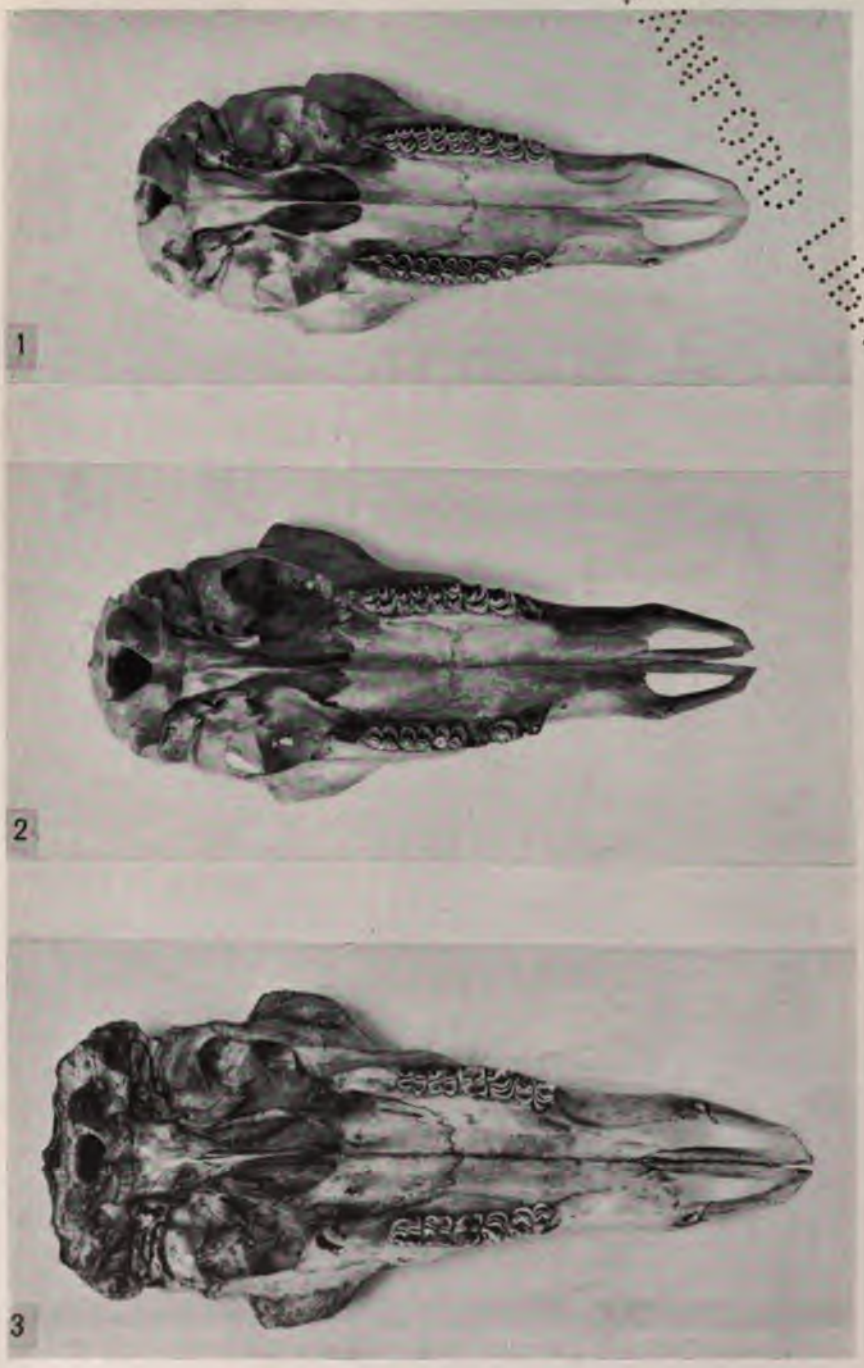
FIG. 3. *R. phylarchus*. ♂ ad. Type. Eastern Kamchatka. (Cat. No. 21343, U. S. N. M.)



TOOTH ROWS OF RANGIFER (Natural Size).

FIGS. 1 AND 1A, R. FORTIDENS; 2 AND 2A, R. OSBORNI; 3, R. MONTANUS.

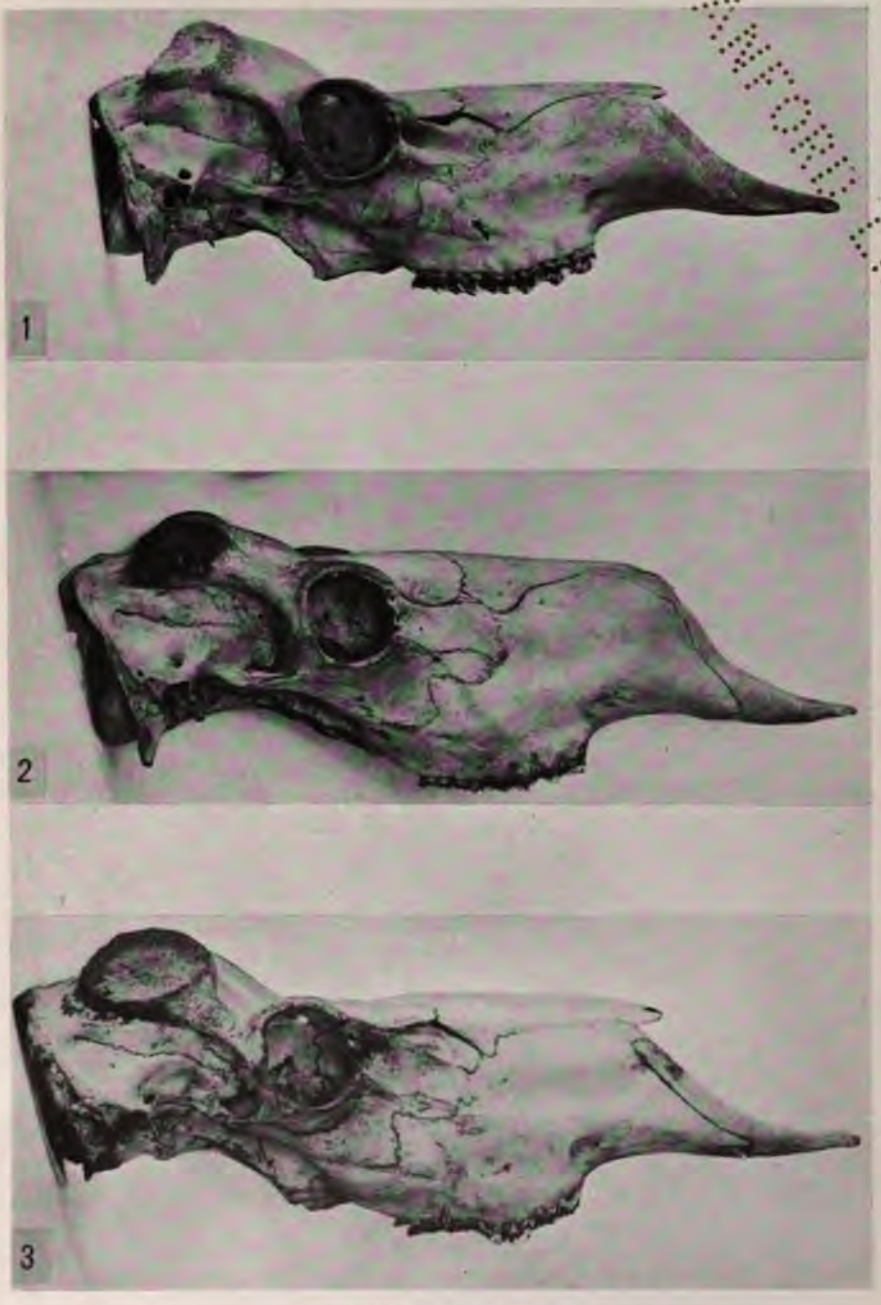
STANFORD LIBRARIES



SKULLS OF RANGIFER (Reduced)

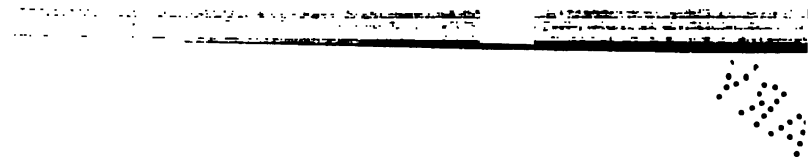
FIG. 1, R. CARIBOU CARIBOU; 2, R. CARIBOU SYLVESTRIS; 3, R. PHYLARCHUS.

Property of the Library
Wesleyan University



SKULLS OF RANGIFER (Reduced)

FIG. 1, R. EXCELSIFRONS; 2 R. ARCTICUS; 3, R. PHYLARCHUS.



SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 56, NUMBER 36

DESCRIPTIONS OF TWELVE NEW SPECIES AND SUBSPECIES OF MAMMALS FROM PANAMA

BY

E. A. GOLDMAN

(PUBLICATION 2073)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
FEBRUARY 19, 1912

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

DESCRIPTIONS OF TWELVE NEW SPECIES AND SUBSPECIES OF MAMMALS FROM PANAMA[1]

By E. A. GOLDMAN

In the early part of 1911 a collection of 368 mammals was made by me while engaged in the biological survey of the Canal Zone, and adjacent parts of Panama, undertaken by the Smithsonian Institution in coöperation with several government departments, including the War Department and the Department of Agriculture. This collection, representing between 40 and 50 genera, includes 12 new species and subspecies which are here published in advance of a general report on the mammals of the region. Nine of the new forms are from the Canal Zone, and the others were taken while on a visit, in March, to the mountains near the headwaters of the Chagres River.

Acknowledgments are due, especially, to Col. George. W. Goethals, U. S. Army, and others connected with the administration of the Canal Zone, who aided materially in the prosecution of the work of the survey. I am also indebted to Dr. J. A. Allen for the privilege of making comparisons with types and other material in the American Museum of Natural History, and to Mr. Samuel Henshaw for the loan of specimens from the Bangs Collection in the Museum of Comparative Zoölogy.

MARMOSA ISTHMICA, sp. nov.

Type from Rio Indio, near Gatun, Canal Zone, Panama. No. 170969, male adult, U. S. National Museum (Biological Survey Collection), collected by E. A. Goldman, February 16, 1911. Original number 20889.

General characters.—Size large, about as in *chapmani* and *ruatanica*, larger than *mexicana, zeledoni* or *mitis;* color about as in *chapmani,* but skull with narrower rostrum, slightly smaller teeth, and decidedly smaller audital processes of alisphenoids.

Color.—General color of upper parts brownish cinnamon, lighter on middle of face, and becoming dull ochraceous buff on sides of

[1] This paper is the sixth dealing with the results of the Smithsonian Biological Survey of the Panama Canal Zone.

neck and flanks; under parts between cream buff and pinkish buff, this color extending to roots of hairs; ears brown; orbital area black; fore feet brownish to base of toes; hind feet and toes of fore feet dull whitish; longer hairs at base of tail on under side tawny ochraceous; tail light brownish.

Skull.—Similar in general to that of *chapmani,* but rostrum narrower; nasals less prolonged posteriorly; audital processes of alisphenoids decidedly smaller; teeth slightly smaller. Differing from that of *ruatanica* in narrower rostrum and more strongly developed subraorbital ridges.

Measurements.—Total length, 385 mm.; tail vertebræ, 215; hind foot, 28. *Skull* (type): Greatest length, 43.5; condylobasal length, 42.7; zygomatic breadth, 23.7; nasals, 20 x 5.1; interorbital breadth, 6.2; palatal length, 21.5; upper molariform toothrow, 13.8; three anterior molariform teeth, 6.2.

Remarks.—A single specimen of this large pale colored species was trapped in an old banana plantation only a few feet above sea level.

METACHIRUS NUDICAUDATUS DENTANEUS, subsp. nov.

Type from Gatun, Canal Zone, Panama. No. 172732, male adult, U. S. National Museum (Biological Survey Collection), collected by E. A. Goldman, January 12, 1911. Original number 20837.

General characters.—Most closely allied to *M. n. colombianus;* color paler, less tawny; skull differing in detail.

Color.—General color of upper parts, including outer sides of hind legs, near wood brown, darkened along back by blackish, the black predominating in a narrow line down middle of rump to tail; median area on top of head glossy black, this color fading gradually by admixture with lighter hairs along a narrowing line reaching anteriorly to nose and posteriorly to back of neck; orbital rings and sides of muzzle blackish; cheeks, supraorbital spots, and area about ears ochraceous buffy, the color richest about ears; shoulders suffused with plumbeous, the basal color being darker and showing through; under parts, including inner sides of limbs, yellowish white; outer sides of fore limbs grayish, tinged with buffy; fore feet mainly dusky, becoming abruptly whitish along outer side of tarsus and on toes; hind feet dull white; tail dusky above, lighter below, becoming whitish all round near tip.

Skull.—Similar in general to that of *colombianus,* but dentition heavier; first, second, and third upper molars more deeply emarginate externally; zygomata lighter.

Measurements.—Type: Total length, 597 mm.; tail vertebræ, 332; hind foot, 48. *Skull* (type): Greatest length, 63; condylobasal length, 61.7; zygomatic breadth, 31.7; nasals 30 x 9.5; interorbital breadth, 9.3; palatal length, 34.5; upper molariform toothrow, 22.2.

Remarks.—In Panama this form seems to be a much rarer animal than *M. fuscogriseus,* which occurs at the same localities and seems to have similar habits. A specimen taken at 2500 feet elevation on Cerro Azul, near the headwaters of the Chagres River is like those from near sea level at Gatun.

Specimens examined.—Total number, 4, from localities as follows:

Canal Zone: Gatun (type locality), 2.

Panama: Cerro Azul, 1.

Costa Rica: Angostura, 1.

SCIURUS VARIEGATOIDES HELVEOLUS, subsp. nov.

Type from Corozal, Canal Zone, Panama. No. 171540, male adult, U. S. National Museum (Biological Survey Collection), collected by E. A. Goldman, June 15, 1911. Original number 21166.

General characters.—Similar in general to *dorsalis* and *variegatoides,* but limbs and under parts paler in the grizzled-back phase; premolars $\frac{1}{1}$ (premolars $\frac{2}{1}$ in *dorsalis*).

Color.—Phase with grizzled back: Top of head and back mixed black and pale buff, the mixture producing a grizzled effect; muzzle and sides of head buffy grayish, much paler than top of head; under parts and limbs pale buff, the color richest on outer sides of forearms, along flanks and on lower base of tail, becoming somewhat paler on feet; ears broadly edged with black anteriorly, more narrowly posteriorly, the ear patches pale buff or white, tail above at base like back, rest of upper side black and white, the hairs broadly tipped with the latter color, below varying along median line from pale ochraceous buff to pale cinnamon-rufous, bordered with black and edged with white. *Variation:* One specimen in worn pelage, perhaps representing the black-backed phase seen in *dorsalis,* has the under parts and limbs uniform pale buffy gray, and the top of head and back blackish in patches. The top of head and back are more uniform in color, and the dark dorsal area broader than in typical examples of *dorsalis* in this phase.

Measurements.—Type: Total length, 508 mm.; tail vertebræ, 255; hind foot, 63. An adult topotype: 540; 274; 67. *Skull* (type): Greatest length, 57.7; condylobasal length, 53; zygomatic breadth, 34.2; nasals, 19.3; interorbital breadth, 21; palatal length, 26.7; maxillary toothrow (small anterior premolar absent), 10.7.

Remarks.—The squirrels of the *S. variegatoides* group are very imperfectly known. The group includes several rather localized forms which in color present a remarkably wide range of individual variation. Large series of typical examples are much needed to make clear many doubtful points. The Panama form is doubtless most closely allied to *dorsalis* of northern Costa Rica, but it seems to differ from typical *variegatoides* mainly in the paler color of the under parts in the phase with grizzled back. The three specimens obtained, two adults and one about half-grown, all lack the small upper premolar usually present in the squirrels of this group.

Specimens examined.—Three, all from the type locality.

MICROSCIURUS ALFARI VENUSTULUS, subsp. nov.

Type from Gatun, Canal Zone, Panama. No. 171030, female adult, U. S. National Museum (Biological Survey Collection), collected by E. A. Goldman, March 1, 1911. Original number 20955.

General characters.—Closely allied to *alfari,* but general color less rufescent. Similar to *browni,* but darker above and below; tail edged with orange rufous instead of grayish white; throat more rusty brown.

Color.—Upper parts, including outer sides of limbs, brownish black, finely grizzled with cinnamon-rufous, or rusty reddish, the general effect resulting from overlapping of black-tipped hairs with rusty reddish subterminal bands; head, and especially cheeks, clearer cinnamon-rufous than back; under parts, including inner sides of limbs, grayish brown, somewhat irregularly suffused with cinnamon-rufous; ears brownish at tips, clothed on inner base with a partly concealed patch of moderately long cream-buffy hairs; feet dark rusty brownish; tail coarsely grizzled black and cinnamon-rufous, rather broadly edged with the latter color.

Skull.—Similar to that of *alfari,* but nasals narrower posteriorly and jugal weaker than in the type of that species.

Measurements.—Type: Total length, 250 mm.; tail vertebræ, 102; hind foot, 40. *Skull* (type): Greatest length, 37; condylobasal length, 32.8; zygomatic breadth, 23.2; nasals, 10.5; interorbital breadth, 14; palatal length, 15; maxillary toothrow (small anterior premolar absent), 5.5.

Remarks.—The pigmy squirrels typified by *alfari* and usually assigned to the subgenus *Microsciurus* constitute a group that seems to merit full generic recognition under this name. Aside from the subgeneric characters currently recognized the group is charac-

terized by simpler dentition than *Sciurus;* the small cusps intermediate in position between the larger tubercles on the outer side in the large upper molariform teeth in *Sciurus* are absent in *Microsciurus.* The skull of the type of *venustulus* lacks the small anterior premolar usually present in *Microsciurus.*

Specimens examined.—Total number, 3, from the following localities:

Canal Zone: Gatun, 2.

Panama: Porto Bello, 1.

ORYZOMYS IDONEUS, sp. nov.

Type from Cerro Azul (altitude 2500 feet), near the headwaters of the Chagres River, Panama. No. 171106, female adult U. S. National Museum (Biological Survey Collection), collected by E. A. Goldman, March 26, 1911. Original number 21010.

General characters.—A large species of the subgenus *Melanomys,* allied to *columbianus,* but larger, with shorter tail; color more rufescent. Differing from *phæopus* and *chrysomelas* in larger size and decidedly paler color.

Color.—Upper parts cinnamon-rufous evenly mixed with black, becoming somewhat paler along flanks; outer sides of limbs dark brownish cinnamon; under parts dark tawny ochraceous, the under color showing through; feet and tail thinly haired, the hairs and epidermis blackish.

Skull.—Closely resembling that of *columbianus,* but decidedly larger; sides of frontals more projecting as supraorbital shelves. Differing from those of *phæopus* and *chrysomelas* mainly in decidedly larger size.

Measurements.—Type: Total length, 218 mm.; tail vertebræ, 88; hind foot, 30. *Skull* (type): Greatest length, 31.5; condylobasal length, 29.5; zygomatic breadth, 17.5; nasals, 12.5; interorbital breadth, 6.5; interparietal, 8.7 x 2.5; incisive foramina, 4.8; length of palatal bridge, 6.5; maxillary toothrow, 4.8.

Remarks.—A single specimen of this rice rat was taken in the humid forest on Cerro Azul. The group to which it belongs bears a marked external resemblance to some species of *Akodon,* and this fact probably led to the publication of *Akodon columbianus* Allen (= Oryzomys columbianus). *O. columbianus* is closely allied to *O. phæopus* and *O. chrysomelas,* and these forms, perhaps along with the one described above, may prove to be intergrading geographic races all assignable to a single widely ranging species.

ORYZOMYS FRONTALIS, sp. nov.

Type from Corozal, Canal Zone, Panama. No. 171531, female adult, U. S. National Museum (Biological Survey Collection), collected by E. A. Goldman, June 20, 1911. Original number 21172.

General characters.—Similar to *O. flavicans*, but decidedly larger; color darker; supraorbital ridges projecting farther over orbits.

Color.—Upper parts between cinnamon-rufous and orange-rufous, darkened on head by more abundant admixed dusky hairs, becoming paler and duller along sides; under parts, including lips and inner sides of limbs white; ears and fore feet brownish; hind feet dull white; tail dusky all round.

Skull.—In general form closely resembling that of *flavicans*, but much larger; supraorbital ridges more developed, the edges less upturned and shelving farther over orbits.

Measurements.—Type: Total length, 309 mm.; tail vertebræ, 161; hind foot, 30. *Skull* (type): Greatest length, 35.5; condylobasal length, 33; zygomatic breadth, 18; nasals, 12; interorbital breadth, 6. 7; interparietal, 10.2 x 5; incisive foramina, 6; length of palatal bridge, 6.7; maxillary toothrow, 5.

Remarks.—The type and only specimen obtained of this large species shows that the animal is clearly a member of the *flavicans* group. It may be not very unlike *O. tectus* Thomas, of Bogava, Chiriqui, which is said to have remarkably expanded supraorbital ridges, but the latter is described as having fulvous upper lips and buffy under parts and feet. The species requires no close comparison with *O. flavicans illectus* which is more orange buffy in color, and has a different skull—the zygomata much less squarely spreading anteriorly, and supraorbital ridges less developed. *O. panamensis* was described from very near the same locality, but was placed in the *laticeps* group.

ORYZOMYS BOMBYCINUS, sp. nov.

Type from Cerro Azul (altitude 2500 feet), near the headwaters of the Chagres River, Panama. No. 171105, male adult, U. S. National Museum (Biological Survey Collection), collected by E. A. Goldman, March 26, 1911. Original number 21009.

General characters.—Similar in color to *carrikeri*, but pelage much longer, and skull more slender. Somewhat like *talamancæ*, but color much darker, and pelage longer and softer; skull with more slender rostrum, and differing in other details.

Color.—Upper parts varying from vandyke brown to mars brown of Ridgway, shaded with black along median line of dorsum, and becoming somewhat paler along sides; face blackish; outer sides of limbs dark brown; under parts dull white, the plumbeous basal color of fur showing through; feet thinly haired, rather dark flesh-colored; tail brownish above, grayish below.

Skull.—Similar in general to that of *talamancæ*, but rostrum more slender; parietals bounded laterally by temporal ridges, instead of extending across them and encroaching on squamosals as in *talamancæ;* frontal region more depressed near posterior ends of nasals.

Measurements.—Type: Total length, 252 mm.; tail vertebræ, 127; hind foot, 32. *Skull* (type): Greatest length, 31.3; condylobasal length, 28.8; zygomatic breadth, 15.4; nasals, 12.2; interorbital breadth, 5.5; interparietal, 8.8 x 4; incisive foramina, 5; length of palatal bridge, 6.2; maxillary toothrow, 4.7.

Remarks.—This rice rat is a dark-colored, long-haired mountain member of the widely ranging *laticeps* group, which includes a number of forms in northern South America, and reaches northward as a group, through Middle America to Mexico. *Oryzomys bombycinus* is remarkable for the length and softness of its pelage.

Specimens examined.—Total number, 4, from localities in Panama, as follows: Cerro Azul (type locality), 3; Cerro Brujo, 1.

ORYZOMYS GATUNENSIS, sp. nov.

Type from Gatun, Canal Zone, Panama. No. 171034, male young, U. S. National Museum (Biological Survey Collection), collected by E. A. Goldman, March 7, 1911. Original number 20967.

General characters.—Allied to *richmondi;* color paler; skull decidedly broader between orbits, the sides of frontals more projecting, interparietal smaller.

Color.—Upper parts between raw umber and tawny olive of Ridgway, mixed with black, the general color becoming brownish on the face and somewhat buffy along flanks; under parts dark pinkish buff, the plumbeous basal color of fur showing through; feet thinly haired, flesh colored; tail grayish brown above, lighter below.

Skull.—Similar in general to that of *richmondi,* but frontal region broader, the lateral margins more developed as supraorbital shelves; interparietal much less extended antero-posteriorly; nasals more

prolonged posteriorly beyond premaxillæ; dentition about as in *richmondi*.

Measurements.—Type: Total length, 224 mm.; tail vertebræ, 115; hind foot, 31.5; *Skull* (type): Greatest length, 27.7; condylobasal length, 24.8; zygomatic breadth, 14.5; nasals, 10.2; interorbital breadth, 5.3; interparietal, 7.3 x 1.5; incisive foramina, 5.6; length of palatal bridge, 5.2; maxillary toothrow, 5.

Remarks.—This species seems to require comparison only with *richmondi*. It is represented by a single specimen taken in an abandoned sugar plantation on the bank of the Chagres River.

ZYGODONTOMYS CHERRIEI VENTRIOSUS, subsp. nov.

Type from Tabernilla, Canal Zone, Panama. No. 171098, male adult, U. S. National Museum (Biological Survey Collection), collected by E. A. Goldman, March 12, 1911. Original number 20975.

General characters.—Similar to *cherriei*, but larger; general color paler and grayer, the back more uniform, less distinctly darkened along median line.

Color.—Upper parts grayish brown, darkest and more or less suffused with yellowish, or light rusty brown, on median dorsal area, becoming paler and grayer along flanks and outer sides of limbs; under parts dull creamy white, or gray, the fur short, and the plumbeous basal color showing through; ears brownish, overlapped at anterior base by rather long rusty hairs; feet white; tail nearly naked, grayish above, whitish below.

Skull.—About like that of *cherriei*, but larger.

Measurements.—Type: Total length, 240 mm.; tail vertebræ, 104; hind foot, 28. Average of ten adult topotypes: 236 (220-255); 102 (94-109); 27.3 (26.5-28). *Skull* (average of four adults): Greatest length, 31.7 (30.5-32.5); condylobasal length, 29.6 (28.5-31); zygomatic breadth, 16.4 (16-17.2); nasals, 12.2 (11.2-13.5); interorbital breadth, 5 (5-5.2); interparietal, 7.7 x 3 (6.3 x 3-9 x 3.5); incisive foramina, 6.7 (6.2-7); length of palatal bridge, 5.5 (5.5-5.5); maxillary toothrow, 4.6 (4.5-4.8).

Remarks.—This form, representing the genus *Zygodontomys* in the Canal Zone, seems to be the most abundant murine rodent in the grassy clearings and second growth jungle of the region. It was not obtained in the heavy forest.

Specimens examined.—Total number, 23, from the following localities in the Canal Zone: Tabernilla (type locality), 15; Gatun, 8.

HETEROMYS PANAMENSIS, sp. nov.

Type from Cerro Azul (altitude 2800 feet), near the headwaters of the Chagres River, Panama. No. 171107, male adult, U. S. National Museum (Biological Survey Collection), collected by E. A. Goldman, March 23, 1911. Original number 20999.

General characters.—Allied to *repens*, but color still darker; fore feet blackish, instead of white, to near base of toes; ankles dusky all round; an ochraceous buffy lateral line sometimes present; sole of hind foot naked, six-tuberculate.

Color.—Ground color of upper parts blackish, nearly clear black on lower part of rump and outer sides of hind legs, becoming slaty grayish along flanks and outer sides of fore legs, the slender ochraceous buffy hairs abundant and producing a grizzled effect; ochraceous buff lateral line present in some specimens, absent in others; under parts white, sometimes suffused with pale buff; fore feet slaty grayish to near base of toes; ankles and proximal third of metatarsus dusky all round; distal two-thirds of metatarsus, and toes of fore and hind feet, whitish; tail varying from blackish above and whitish below to dark nearly unicolor all round.

Skull.—Similar to that of *repens*, but rostrum broadening more abruptly to zygomata; interparietal broader; lateral wings of supraoccipital narrower, less developed over mastoids.

Measurements.—Type: Total length, 283 mm.; tail vertebræ, 148; hind foot, 35. *Skull* (type): Greatest length, 35.5; zygomatic breadth, 17.1; interorbital breadth, 9.4; nasals, 14.4; width of braincase, 15.2; interparietal, 10 x 5.5; maxillary toothrow, 5.2.

Remarks.—On the mountains near the headwaters of the Chagres River this very dark spiny pocket mouse was found inhabiting the forests from 2000 feet upward to the summit at about 3000 feet altitude. The same species was also obtained at about 2000 feet altitude on Cerro Brujo, near the north coast. It is more nearly related to *repens* of Chiriqui, than to *zonalis*, a near geographic neighbor of the lowlands in the Canal Zone.

Specimens Examined.—Six, all from Panama, as follows: Cerro Azul (type locality), 5; Cerro Brujo, 1.

HETEROMYS ZONALIS, sp. nov.

Type from Rio Indio (near Gatun), Canal Zone, Panama. No. 170976, female adult, U. S. National Museum (Biological Survey Collection), collected by E. A. Goldman, February 15, 1911. Original number 20885.

General characters.—Size about as in *desmarestianus,* but color darker, the slender hairs paler and less conspicuous among the bristles over dorsum; lateral line absent; white of under parts continuous along inner side of hind leg to foot; skull massive; maxillary root of zygomata broad and heavy; interparietal rather narrow, with a well-developed anterior angle, and a small posterior median notch.

Color.—Upper parts blackish, becoming dark mouse gray along flanks and outer sides of limbs, the slender hairs inconspicuous among the black-tipped bristles; under parts, feet, and a line down inner side of hind leg to metatarsus, white; tail blackish or brownish above, whitish below, except at base where it is dark all round as usual in the group.

Skull.—Similar to that of *desmarestianus,* but interparietal with a more prominent anterior angle, and a posterior median notch (the latter absent in *desmarestianus*); parietals less extended laterally across temporal ridges; dentition about the same.

Measurements.—Type: Total length, 263 mm.; tail vertebræ, 134; hind foot, 35. *Skull* (type): Greatest length, 37; zygomatic breadth, 17; interorbital breadth, 10; nasals, 15.2; width of braincase, 15.2; interparietal, 8.2 x 5; maxillary toothrow, 5.5.

Remarks.—Although so widely separated geographically this species seems more like typical *desmarestianus* of Guatemala than like its near neighbors in Panama. It lives at low elevations on rocky heavily forested hills in the northern end of the Canal Zone.

Specimens examined.—Four, all from the vicinity of the type locality.

HOPLOMYS GOETHALSI,[1] sp. nov.

Type from Rio Indio, near Gatun, Canal Zone, Panama. No. 170972, young female, U. S. National Museum (Biological Survey Collection), collected by E. A. Goldman, February 16, 1911. Original number 20888.

General characters.—In size and color similar to *truei* and *gymnurus;* skull with heavier zygomata than either, the jugal decidedly broader, with inferior border projecting posteriorly in a well defined hook (absent in *truei* and *gymnurus*).

[1] Named in honor of Col. George W. Goethals, U. S. Army, Chairman and Chief Engineer of the Isthmian Canal Commission, whose courtesy and assistance have contributed so much to the success of the Smithsonian Biological Survey of the Panama Canal Zone.

Color.—Ground color of upper parts cinnamon-rufous, darkened on top of head and along median line of neck by slender bristles which are replaced from near shoulders to rump by stout, anteriorly-grooved, black-tipped spines projecting beyond and overlying the finer hairs; cheeks and outer sides of fore limbs grayish brown, the cheeks in a fully adult example suffused with cinnamon-rufous; outer sides of hind limbs blackish; under parts white, interrupted in some specimens by a more or less complete pectoral band; nose and sides of muzzle blackish; ankles dark all round; inner side of metatarsus and three inner digits whitish, outer side and two outer digits brownish; tail blackish above, whitish below.

Skull.—General form resembling that of *truei,* but jugal more extended vertically, the inferior border more produced anteriorly, reaching nearer to antorbital foramen, and more prolonged posteriorly to form a distinct hook. Similar to *gymnurus,* but parietals more developed below temporal ridges; squamosal reaching farther along lateral ridges near frontoparietal suture; audital bullæ larger; zygomata differing in about the same characters as from *truei;* dentition the same as in the type species of the genus.

Measurements.—Type: Total length, 391 mm.; tail vertebræ, 153; hind foot, 54. An old male topotype: 529; 244; 62.5. *Skull* (type): Condylobasal length, 51.6; zygomatic breadth, 29.2; interorbital breadth, 13; palatal length, 20; length of palatal bridge, 11.8; width of jugal near middle, 3.8; maxillary toothrow, 9.3.

Remarks.—The Isthmian representative of this genus agrees closely with *truei* and *gymnurus* in color and remarkably stout spiny armature, but is readily distinguished by the cranial characters pointed out. The posterior prolongation of the lower border of the jugal to form a process or hook is a character present also in some species of *Prœchimys,* and absent in others.

Specimens examined.—Three, from the type locality.

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 56. NUMBER 37

DESCRIPTIONS OF TWO NEW SPECIES OF NUN BIRDS FROM PANAMA

BY

E. W. NELSON

(PUBLICATION 2074)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
FEBRUARY 16, 1912

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

DESCRIPTIONS OF TWO NEW SPECIES OF NUN BIRDS FROM PANAMA[1]

By E. W. NELSON

Two new species of *Monasa* are among the interesting birds collected by E. A. Goldman while working on the Smithsonian Biological Survey of Panama during the winter of 1911. They were collected at the same locality on the base of Cerro Azul, northwest from Chepo, and only a single specimen of each was obtained. No others were seen during the entire season in the Canal Zone and adjacent territory. I wish to express my obligation to Mr. Robert Ridgway, Curator of Birds, U. S. National Museum for his aid in the determination of the status of the species described here.

MONASA FIDELIS, new species

Goldman's Nun Bird

Type No. 207666, adult male, U. S. National Museum, Biological Survey Collection; collected on Cerro Azul, Panama (altitude 800 feet), March 21, 1911, by E. A. Goldman (original number 14127).

Distribution.—Known from type locality only.

Specific characters.—Much like *grandior* of Costa Rica, but anterior point of feathered malar area white as in *morphœus* from eastern Brazil, and black of head and neck extending farther back, and more abruptly defined posteriorly, reaching front of back above and middle of breast below; wing coverts paler gray than in *grandior* but much darker than in *pallescens*.

Measurements.—Wing, 134; tail, 115; tarsus, 21; culmen, 41.

MONASA SIMILIS, new species

Cerro Azul Nun Bird

Type No. 207665, adult female, U. S. National Museum, Biological Survey Collection; collected on Cerro Azul, Panama (altitude 800 feet) March 24, 1911, by E. A. Goldman (original number 14180).

Distribution.—Known from type locality only.

[1] This paper is the seventh dealing with the results of the Smithsonian Biological Survey of the Panama Canal Zone.

Specific characters.—In general coloration very similar to *M. fidelis* from the same locality but immediately distinguishable by absence of white on chin, this color being confined to a band about base of upper mandible extending to lores as in *pallescens;* black of head and neck extends over entire neck and on fore part of back and over most of breast; posterior border of black not sharply defined as in *fidelis* but shading into the slaty color of body; color of wings, tail and rest of body the same in both these species.

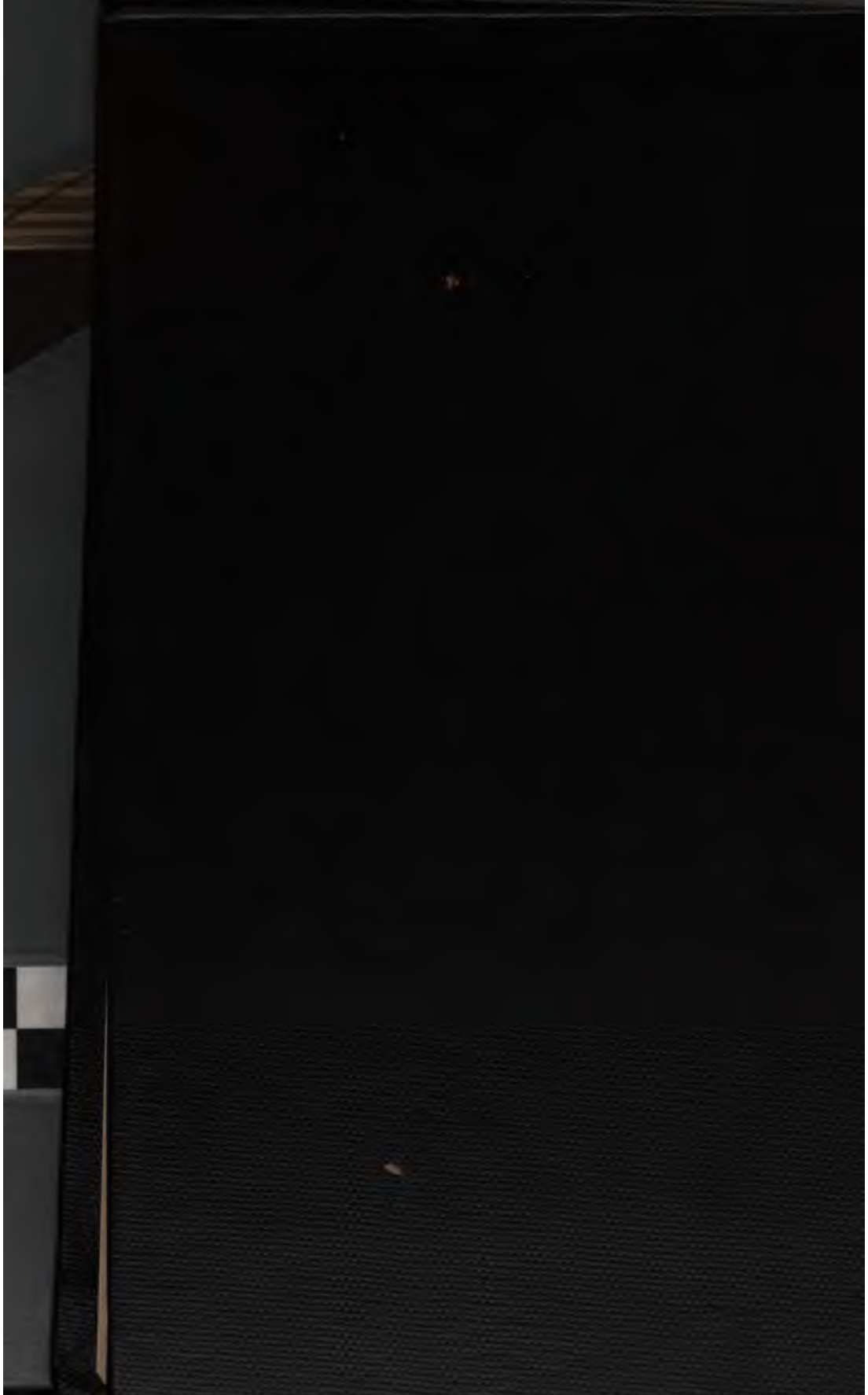
Measurements.—Wing, 138 mm.; tail, 129; tarsus, 22; culmen, 42.5.

5c
564
56

DATE DUE

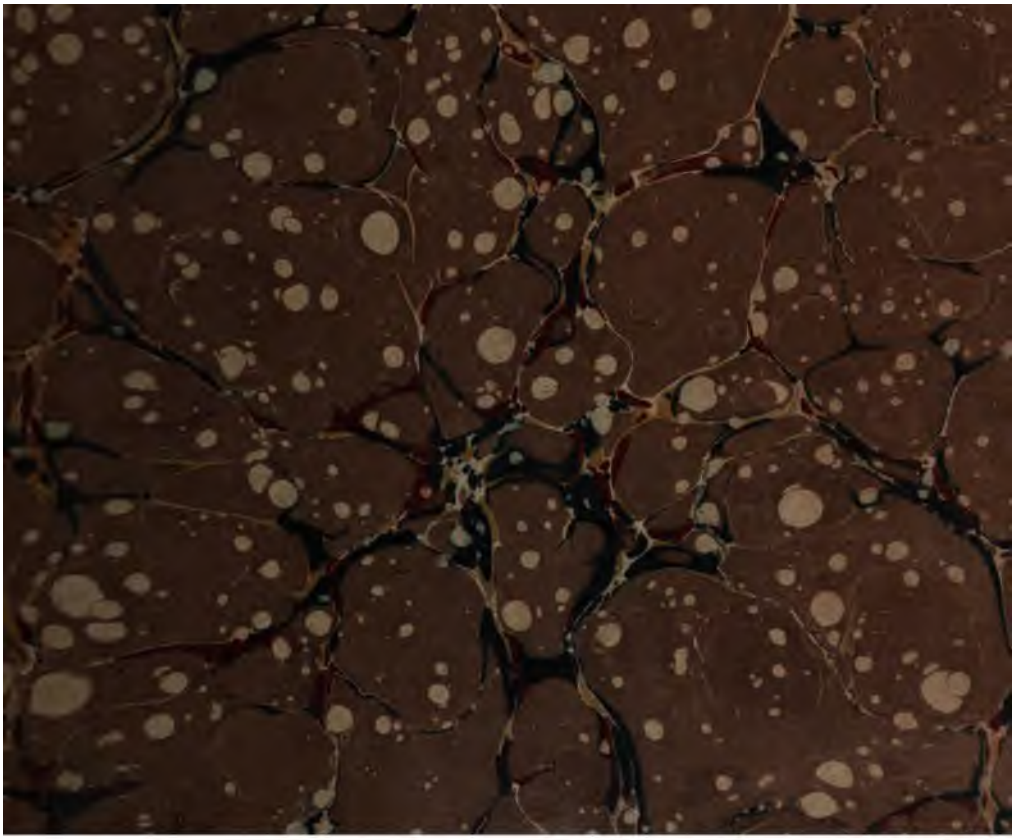
STANFORD UNIVERSITY LIBRARIES
STANFORD AUXILIARY LIBRARY
STANFORD, CALIFORNIA 94305-6004
(650) 723-9201
salcirc@sulmail.stanford.edu
All books are subject to recall.
DATE DUE

NOV 2 0 1999
NOV 2 0 1999



506 .S664M V.58 C.2
... Bibliography of th
Stanford University Libraries
3 6105 046 404 534

LELAND·STANFORD·JVNIOR·VNIVERSITY



11346-5-7221

SMITHSONIAN MISCELLANEOUS COLLECTIONS

VOL. 58

"EVERY MAN IS A VALUABLE MEMBER OF SOCIETY WHO, BY HIS OBSERVATIONS, RESEARCHES, AND EXPERIMENTS, PROCURES KNOWLEDGE FOR MEN"—SMITHSON

(PUBLICATION 2160)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
1912

179615

STANFORD LIBRARY

ADVERTISEMENT

The present series, entitled "Smithsonian Miscellaneous Collections," is intended to embrace all the octavo publications of the Institution, except the Annual Report. Its scope is not limited, and the volumes thus far issued relate to nearly every branch of science. Among these various subjects zoölogy, bibliography, mineralogy, and anthropology have predominated.

The Institution also publishes a quarto series entitled "Smithsonian Contributions to Knowledge." It consists of memoirs based on extended original investigations, which have resulted in important additions to knowledge.

CHARLES D. WALCOTT,
Secretary of the Smithsonian Institution.

Washington, D. C., December 18, 1912.

CONTENTS

1. **Fowle**, F. E. Smithsonian Physical Tables. Fifth revised edition. Published 1910. XXXIV, 318 pp. (Pub. No. 1944.)

2. **Hess**, Frank L. and Eva. Bibliography of the Geology and Mineralogy of Tin. Published 1912. V, 408 pp. (Pub. No. 1987.)

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 58, NUMBER 1

SMITHSONIAN PHYSICAL TABLES

FIFTH REVISED EDITION

PREPARED BY
F. E. FOWLE
AID, SMITHSONIAN ASTROPHYSICAL OBSERVATORY

(PUBLICATION 1944)

STANFORD LIBRARY

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
1910

PUBLIC LIBRARY

ADVERTISEMENT.

In connection with the system of meteorological observations established by the Smithsonian Institution about 1850, a series of meteorological tables was compiled by Dr. Arnold Guyot, at the request of Secretary Henry, and the first edition was published in 1852. Though primarily designed for meteorological observers reporting to the Smithsonian Institution, the tables were so widely used by physicists that it seemed desirable to recast the work entirely. It was decided to publish three sets of tables, each representative of the latest knowledge in its field, and independent of one another, but forming a homogeneous series. The first of the new series, Meteorological Tables, was published in 1893, the second, Geographical Tables, in 1894, and the third, Physical Tables, in 1896. In 1909 yet another volume was added, so that the series now comprises: Smithsonian Meteorological Tables, Smithsonian Geographical Tables, Smithsonian Physical Tables, and Smithsonian Mathematical Tables.

The fourteen years which have elapsed since the publication of the first edition of the Physical Tables, prepared by Professor Thomas Gray, have brought such changes in the material upon which the tables must be based that it became necessary to prepare this almost wholly new set of tables for the present edition.

CHARLES D. WALCOTT,
Secretary, Smithsonian Institution.

June, 1910.

PREFACE.

The present Smithsonian Physical Tables are the outcome of a critical revision of the set of tables compiled by Professor Thomas Gray in 1896. Recent data and many new tables have been added for which the references to the sources have been made more complete; and several mathematical tables have been added, — some of them especially computed for this work. The inclusion of these mathematical tables seems warranted by the demand for them. In order to preserve a uniform change of argument and to facilitate comparison, many of the numbers given in some tables have been obtained by interpolation in the data actually given in the papers quoted.

Our gratitude is expressed for many suggestions and for help in the improvement of the present edition: to the U. S. Bureau of Standards for the revision of the electrical, magnetic, and metrological tables and other suggestions; to the U. S. Coast and Geodetic Survey for the revision of the magnetic and geodetic tables; to the U. S. Geological Survey for various data; to Mr. Van Orstrand for several of the mathematical tables; to Mr. Wead for the data on the musical scales; to Mr. Soreau for the new physical-chemistry data; to Messrs. Abbot, Becker, Davis, Rosa, and Wood; to the U. S. Bureau of Forestry and to others. We are also under obligation to the authors and publishers of Landolt-Börnstein-Meyerhoffer's Physikalisch-chemische Tabellen (1905) and B. O. Peirce's Mathematical Tables for the use of certain tables.

It is hardly possible that any series of tables involving so much transcribing, interpolation, and calculation should be entirely free from errors, and the Smithsonian Institution will be grateful, not only for notice of whatever errors may be found, but also for suggestions as to other changes which may seem advisable for later editions.

F. E. Fowle.

Astrophysical Observatory
of the Smithsonian Institution,
June, 1910

TABLE OF CONTENTS

PAGE

Introduction on units of measurement and conversion factors . . xv
Units of measurement: general discussion xv
Dimension formulæ for dynamic units xvii
" " " heat units xxiii
" of electric and magnetic units: general discussion . . xxv
" formulæ in electrostatic system xxvi
" " " electromagnetic system xxix
Practical units of electricity, legalization of xxxiii

TABLE

1. Formulæ for conversion factors: (*a*) Fundamental units . . . 2
(*b*) Derived units . . . 2
I. Geometric and dynamic units 2
II. Heat units 3
III. Magnetic and electric units 3
2. Tables for converting U. S. weights and measures:
(1) Customary to metric 5
(2) Metric to customary 6
3. Equivalents of metric and British imperial weights and measures:
(1) Metric to imperial 7
(2) Multiples, metric to imperial 8
(3) Imperial to metric 9
(4) Multiples, imperial to metric 10
4. Volume of a glass vessel from weight of its volume of water or mercury 11
5. Elementary differential coefficients and integrals 12
6. Reciprocals, squares, cubes and square roots of natural numbers . 13
7. Logarithms, 1000–2000 22
8. Logarithms 24
9. Antilogarithms 26
10. Antilogarithms, .9000–1.0000 28
11. Circular (trigonometric) functions, argument (°, ′.) 30
12. " " " argument (radians) . . . 35
12a. Factorials, n!, n = 1 to 100 38
13. Values of $\frac{e^x - e^{-x}}{2}$ (hyperbolic sines), for values of x from 0 to 5 . 39
14. Logarithms of $\frac{e^x - e^{-x}}{2}$ (hyperbolic sines), for values of x from 0 to 5 . 40
15. Values of $\frac{e^x + e^{-x}}{2}$ (hyperbolic cosines), for values of x from 0 to 5 . 41

16. Logarithms of $\frac{e^x+e^{-x}}{2}$ (hyperbolic cosines) for values of x from 0 to 5 42
17. Values of e^x and e^{-x} and their logarithms for x from 0 to 10 . . 43
18. " " log. e^x for values of x from 10 to 30 44
19. " " e^{x^2} and e^{-x^2} and their logarithms 45
20. " " $e^{\frac{\pi}{4}x}$ and $e^{\frac{-\pi}{4}x}$ " " " 46
21. " " $e^{\frac{\sqrt{\pi}}{4}x}$ and $e^{\frac{-\sqrt{\pi}}{4}x}$ " " 46
22. " " e^x and e^{-x} and " " for fractional values of x . 47
23. Probability of errors of observations: probability integral . . . 47
24. " " " " " " " " . . . 48
25. Values of $0.6745\sqrt{\frac{1}{n-1}}$ 48
26. " " $0.6745\sqrt{\frac{1}{n(n-1)}}$ 49
27. " " $0.8453\sqrt{\frac{1}{n(n-1)}}$ 49
28. " " $0.8453\frac{1}{n\sqrt{n-1}}$ 49
29. Inverse of probability integral. Diffusion 50
30. Logarithms of the gamma function $\Gamma(n)$ for values of n between 1 and 2 52
31. Values for the first seven zonal harmonics from $\theta=0°$ to $\theta=90°$. 54
32. " " log. $M/4\pi\sqrt{aa^1}$ for facilitating the calculation of the mutual inductance between two coaxial circles 56
33. Value for $\int_0^{\frac{\pi}{2}}(1-\sin^2\theta\sin^2\phi)^{\pm\frac{1}{2}}d\Phi$ for different values of θ; also the corresponding logarithms 57
34. Moments of inertia, radii of gyration, corresponding weights . . 58
35. British standard wire gauge: diameters, sections 59
36. Birmingham wire gauge " " 59
(For Brown and Sharp gauge, see tables 40 and 41)
37. Cross section and weights of wires (copper, iron, brass), British units . 60
38. " " " " " " " " " metric units . 62
39. " " " " " aluminum wire: British and metric units . 64
40. Size, weight and electrical constants of copper wire, Brown and Sharp gauge: common units 66
41. Same as table 40, but in metric measure 68
42. Weight in grammes per square metre of sheet metal 70
43. " " various common units of sheet metal 70
44. Strength of materials: (*a*) metals 71
(*b*) stones 71
(*c*) brick 71
(*d*) concretes 71
45. " " " timber tests 72
" " " " " 73
oduli of rigidity 74

47a. Variation of the moduli of rigidity with the temperature . . . 74
48. Young's modulus 75
49. Compressibility of the more important solid elements 76
50. Hardness 76
51. Relative hardness of the elements 76
52. Poisson's ratio 76
53. Elastic moduli of crystals, formulæ 77
54. " " " " numerical results 78
55. Compressibility of O, air, N, H at different pressures and temperatures 79
56. " " ethylene " " " " " . 79
57. " " " " " " " " . 79
58. " " carbon dioxide at " " " " . 80
59. " " gases, values of α 80
60. " " air and oxygen between 18° and 22°C . . . 80
61. Relation between pressure, temperature and volume of sulphur dioxide 81
62. " " " " " " " ammonia . 81
63. Compressibility of liquids 82
64. " " " 83
65. Specific gravities corresponding to the Beaumé scale 84
66. Densities of the solid and liquid elements 85
67. " " various woods 87
68. " " " solids 88
69. " " " alloys 89
70. " " " liquids 90
71. " " " gases 91
72. " " " aqueous solutions of salts, bases and acids . . 92
73. Density of water between 0° and 36° C 94
74. Volume of water at temperatures between 0° and 36° C in terms of its volume at the temperature of maximum density 95
75. Density and volume of water at different temperatures from −10 to 250°C 96
76. " " " " mercury at " " " −10 " 360°C 97
77. Specific gravity of aqueous ethyl alcohol 98
78. Density of aqueous methyl alcohol 99
79. Variation of the density of alcohol with the temperature . . . 100
80. Velocity of sound in solids 101
81. " " " " liquids and gases 102
82. Musical scales 103
83. " " 103
84. Force of gravity at sea level and different latitudes 104
85. Results of some of the more recent gravity determinations . . . 105
86. Value of gravity at some of the U. S. C. and G. Survey stations . . 106
87. Length of seconds pendulum for sea level and different latitudes . 107
88. Determinations of the length of the seconds pendulum . . . 107
89. Miscellaneous data as to the earth and planets 108
90. Terrestrial magnetism: secular change of declination . . . 110
91. " " dip or inclination 112
92. " " secular change of dip 112
93. " " horizontal intensity 113

94. Terrestrial magnetism: secular change of horizontal intensity . . 113
95. " " total intensity 114
96. " " secular change of total intensity . . . 114
97. " " agonic line 115
98. Pressure of mercury and water columns 116
99. Reduction of barometer to standard temperature 117
100. " " " " " gravity, inch and metric scales . 118
101. " " " " latitude 45°: inch scale 119
102. " " " " " " metric scale 120
103. Correction of barometer for capillarity: inch and metric scale . . 121
104. Aerodynamics: data for wind pressures 122
105. " " " the soaring of planes 123
106. Coefficients of friction 124
107. Viscosity of water at different temperatures 125
108. Coefficients of viscosity for solutions of alcohol in water . . . 126
109. Specific viscosity of mineral oils 126
110. " " " various oils 126
111. " " " " liquids 127
112. " " " " " temperature variation . . . 128
113. " " " solutions: variation with density and temperature . 129
114. " " " " atomic concentrations 133
115. " " " gases and vapors 134
116. " " " " " " temperature variation . . 135
117. Diffusion of an aqueous solution into pure water 136
118. " " vapors 137
119. " " gases and vapors 138
119*a*. " " metals into metals 138
120. Solubility of inorganic salts in water: temperature variation . . 139
121. " " a few organic salts in water: temperature variation . . 140
122. " " gases in water 140
123. Absorption of gases by liquids 141
124. Capillarity and surface tension: water and alcohol in air . . . 142
125. " " " " miscellaneous liquids in air . . 142
126. " " " " aqueous solutions of salts . . . 142
127. Capillarity and surface tension: liquids in contact with air, water or mercury 143
128. Capillarity and surface tension: liquids at solidifying point . . . 143
129. " " " " thickness of soap films . . . 143
130. Vapor pressures 144
131. " " of ethyl alcohol 146
132. " " " methyl " 146
133. " " and temperatures: (*a*) carbon disulphide . . . 147
(*b*) chlorobenzine . . . 147
(*c*) bromobenzine . . . 147
(*d*) aniline 147
(*e*) methyl salicylate . . . 148
(*f*) bromonaphthaline . . . 148
(*g*) mercury 148

134. Vapor pressures of solutions of salts in water 149
135. Pressure of aqueous vapor at low temperatures 151
136. " " " " 0° to 100° C (Broch) 152
137. " " " " 100° to 230° C (Regnault) 153
138. Weight in grains of aqueous vapor in a cubic foot of saturated air . 154
139. " " grammes of " " " " " metre of " " . 154
140. Hygrometry, vapor pressure in the atmosphere 155
141. " dew-points 156
142. Relative humidity 158
143. Values of $0.378e$ in the atmospheric pressure equation $h = B - 0.378e$. 159
144. Table for facilitating the calculation of $h/760$ 160
145. Logarithms of $h/760$ for values of h between 80 and 800 . . . 160
146. Values of $1 + 0.00367\,t$:
(*a*) for values of t between 0° and 10° C, by tenths . . . 162
(*b*) " " " " " —90° " +1990° C, by tens . . 163
(*c*) logarithms for t " —49° " +399° C, by units . . 164
(*d*) " " " " 400° " 1990° C, by tens . . . 166
147. Determination of heights by the barometer 167
148. Barometric pressures corresponding to different temperatures of the boiling-point of water:
(*a*) Common measure 168
(*b*) Metric measure 169
149. Standard wave-lengths: Fabry-Buisson's iron arc lines . . . 170
150. " " " red cadmium line 170
151. Stronger lines of some of the elements 170
152. Rowland's standard solar wave-lengths (also corrections) . . . 171
153. Kayser's standard iron arc lines (also corrections) 174
154. Wave-lengths of the Fraunhofer lines 176
155. Photometric standards 177
156. Sensitiveness of the eye to radiation of different wave-lengths: low (threshold) intensities 178
157. Sensitiveness of the eye: greater intensities 178
158. Sensibility of the eye to small differences of intensity (Fechner) . . 178
159. Solar energy and its absorption by the earth's atmosphere . . . 179
160. The solar "constant" of radiation and temperature of sun . . . 179
161. Distribution of intensity of radiation over solar disk 179
162. Relative intensities of sunlight and sky-light 179
163. Indices of refraction of Jena glasses 180
164. " " " " " " 180
165. " " " " " " temperature coefficients . . 180
166. " " " " various alums 181
167. " " " " metals and metallic oxides:
(*a*) Kundt's experiments 182
(*b*) Du Bois and Rubens' experiments 182
(*c*) Drude's experiments 182
168. Indices of refraction for rock salt 183
169. " " " " " " temperature coefficients . . 183
170. " " " " sylvine 183

171. Indices of refraction for fluorite 184
172. " " " " " temperature coefficients . . . 184
173. " " " " Iceland spar 184
174. " " " " nitroso-dimethyl-aniline 184
175. " " " " quartz 185
176. " " " " various monorefringents 186
177. " " " " " uniaxial crystals 187
178. " " " " " biaxial crystals 187
179. " " " " solutions of salts and acids:
(*a*) solutions in water 188
(*b*) " " alcohol 188
(*c*) " " potassium permanganate . 188
180. " " " " various liquids 189
181. " " " " gases and vapors 190
182. Reflection of light, perpendicular incidence: various values of n . . 191
183. " " " incidence varying: n near unity 191
184. " " " " " $n = 1.55$ 191
185. Reflection from metals 192
186. Transmission of Jena glasses 193
187. " " " " 193
188. " " " ultra-violet glasses 193
189. " " alum, rock salt, sylvine, fluorite, Iceland spar, quartz 194
190. Color screens (Landolt) 195
191. " " (Wood) 195
192. " " (Jena glasses) 196
193. Rotation of the plane of polarized light by solutions 197
194. " " " " " " " " sodium chlorate and quartz 197
195. Colors of thin films, Newton's rings 198
196. Thermal conductivity of metals and alloys 199
197. " " " various substances 200
198. " " " water and salt solutions 200
199. " " " organic liquids 200
200. " " " gases 200
201. Heat of combustion 201
202. Heat values and analyses of various fuels: (*a*) coals 202
(*b*) peats 202
(*c*) liquid fuels . . . 202
203. Chemical and physical properties of explosives 203
204. Heat of combination 204
205. Latent heat of vaporization 206
206. " " " fusion 208
207. Melting-points of the chemical elements 209
208. Boiling-points " " " " 210
209. Melting-points of various inorganic compounds 211
210. Boiling-points " " " " 213
211. Melting points of various mixtures of metals 214
" " " " " " " 214
-melting-point alloys 214

214. Densities, melting-points, boiling-points of organic compounds:
(*a*) Paraffin series 215
(*b*) Olefine series 215
(*c*) Acetylene series 216
(*d*) Monatomic alcohols 216
(*e*) Alcoholic ethers 216
(*f*) Ethyl ethers 216
215. Lowering of freezing-points by salts in solution 217
216. Raising of boiling-points by salts in solution 219
217. Freezing mixtures 220
218. Critical temperatures, pressure, volumes and densities of gases . . 221
219. Coefficients of linear expansion of the chemical elements . . . 222
220. " " " " " miscellaneous substances . . 223
221. " " cubical " " crystalline and other solids . . 224
222. " " " " " liquids 225
223. " " thermal expansion of gases 226
224. Mechanical equivalent of heat: various data 227
225. " " " " adopted values (Ames) . . . 227
226. " " " " conversion values 227
227. Specific heats of the chemical elements 228
228. " " " water and mercury 229
229. " " " various solids 230
230. " " " " liquids 230
231. " " " " minerals and rocks 231
232. " " " " gases and vapors 232
233. Gas and mercury thermometers: formulæ 233
234. Comparison of hydrogen and 16^{III} thermometers: 0° to 100° C. . . 233
235. " " " " 59^{III} " 0° to 100° C. . . 233
236. " " " " 16^{III} and 59^{III} thermometers: −5° to −35° C. 233
237. Comparison of air and 16^{III} glass thermometers: 0° to 300° C. . . 234
238. " " " " 59^{III} " " 100° to 200° C. . 234
239. " " hydrogen and various mercury thermometers . . 235
240. " " air and high temperature (59^{III}) mercury thermometer . 235
241. " " H., toluol, alcohol, petrol ether, pentane thermometers 235
242. Stem correction for thermometers 236
243. " " " " 237
244. " " " " 237
245. Radiation formulæ and constants for perfect radiator 238
246. " in calories for perfect radiators at various temperatures . 238
247. " distribution in spectrum at various temperatures . . . 238
248. Cooling by radiation and convection; ordinary pressures . . . 239
249. " " " " " different pressures . . . 239
250. " " " " " very small pressures . . . 240
251. Cooling by radiation and convection: temperature and pressure effects 240
252. Properties and constants of saturated steam: metric measure . . 241
253. " " " " " " common measure . . 242
254. Ratio of the electrostatic to the electromagnetic unit of electricity . 247

255. Dielectric strength; steady potential for spark in air 24
256. " " alternating potential for spark in air . . . 24
257. " " potentials for longer sparks in air . . . 24
258. " " effect of (air) pressure 24
259. " " of various materials 25
260. " " " kerosene 25
261. Electromotive force of standard cells: absolute current measures . 25
262. Data for voltaic cells: (*a*) double fluid cells 25
(*b*) single fluid cells 25
(*c*) standard cells 25
(*d*) secondary (storage) cells 25
263. Contact differences of potential, solids with liquids and liquids with liquids in air 25
264. Contact differences of potential, solids with solids in air . . . 25
265. Potential difference between metals in various salt solutions . . 25
266. Thermoelectric powers 25
267. " " with platinum 25
268. Peltier effect 26
269. Various determinations of the ohm 26
270. Specific resistance of metallic wires 26
271. " " " metals 26
272. Resistance of metals and alloys at low temperatures 26
273. Conductivity of three-metal and miscellaneous alloys 26
274. Conducting power of alloys 26
275. Electric resistance with alternating currents (straight wires) . . 26
276. International atomic weights and electrochemical equivalents . . 27
277. Conductivity of a few dilute solutions 27
278. Electrochemical equivalents and densities of nearly normal solutions . 27
279. Specific molecular conductivity of solutions 27
280. " " " " " limiting values . . . 27
281. " " " " " temperature coefficients . 27
282. Equivalent conductivity of salts, acids, bases in solution . . . 27
283. " " " some additional salts in solution . . 27
284. " conductance of the separate ions 27
285. Hydrolysis of ammonium acetate: ionization of water 27
286. Dielectric constants (specific inductive capacity) of gases . . . 27
287. " " " " " " " temperature coefficient 27
288. Dielectric constants (specific inductive capacity) of gases: pressure coefficient 27
289. Dielectric constants of liquids 28
290. " " " " temperature coefficient . . . 28
291. " " liquefied gases 28
292. " " standard solutions for calibrations . . . 28
293. Dielectric constants of solids 28
294. " " " crystals 28
295. Temperature variation of electrical resistance of glass, porcelain . . 28
296. Permeability of iron rings and wire, various inductions . . . 28

297. Permeability of transformer iron :
(*a*) specimen of Westinghouse No. 8 transformer . . . 286
(*b*) " " " " 6 " . . . 287
(*c*) " " " " 4 " . . . 287
(*d*) " " Thomson-Houston 1500-watt transformer . . 287
298. Magnetic properties of iron and steel 288
299. " " " cast iron in intense fields 288
300. " corrections for ring specimens 288
301. Demagnetizing factors for rods 289
302. " " Shuddemagen's values 289
303. Composition and magnetic properties of iron and steel . . . 290
304. Permeability of some of the specimens in Table 303 . . . 292
305. Magnetic properties of soft iron at 0° and 100° C. 292
306. " " " steel at 0° and 100° C. 292
307. " " " cobalt at 100° C. 293
308. " " " nickel " " " 293
309. " " " magnetite 293
310. " " " Lowmoor wrought iron 293
311. " " " Vicker's tool steel 293
312. " " " Hadfield's manganese steel . . . 293
313. Saturation values for different steels 293
314. Magnetic properties of iron in very weak fields 294
315. Dissipation of energy in cyclic magnetization of magnetic substances . 294
316. " " " " " " " cable transformers . 294
317. " " " " " " " various substances . 295
318. " " " " " " " transformer steels . 296
319. Magneto-optic rotation, formulæ: Verdet's constant 297
320. " " " in solids 298
321. " " " " liquids 299
322. " " " " solutions of salts and acids in water . . 301
323. " " " " " " " in alcohol . . . 303
324. " " " " " " " hydrochloric acid . . 303
325. " " " " gases 304
326. Verdet's and Kundt's constants 304
327. Magnetic susceptibility of liquids and gases 305
328. Values of Kerr's constant 305
329. Variation of the resistance of bismuth in magnetic field . . . 306
330. " " " " " nickel " " " . . . 306
331. " " " " " various metals in a magnetic field . . 306
332. Transverse galvanomagnetic and thermomagnetic effects . . . 307
333. Variation of the Hall constant with the temperature . . . 307
334. Appendix: Mean specific heat of iron at high temperatures . . . 308
335. " Total heat of iron to high temperatures 308
— " Definitions of units 309

Index 313

INTRODUCTION.

UNITS OF MEASUREMENT AND CONVERSION FORMULÆ.

Units. — The quantitative measure of anything is a number which expresses the ratio of the magnitude of the thing to the magnitude of some other thing of the same kind. In order that the number expressing the measure may be intelligible, the magnitude of the thing used for comparison must be known. This leads to the conventional choice of certain magnitudes as units of measurement, and any other magnitude is then simply expressed by a number which tells how many magnitudes equal to the unit of the same kind of magnitude it contains. For example, the distance between two places may be stated as a certain number of miles or of yards or of feet. In the first case, the mile is assumed as a known distance; in the second, the yard, and in the third, the foot. What is sought for in the statement is to convey an idea of the distance by describing it in terms of distances which are either familiar or easily referred to for comparison. Similarly quantities of matter are referred to as so many tons or pounds or grains and so forth, and intervals of time as a number of hours or minutes or seconds. Generally in ordinary affairs such statements appeal to experience; but, whether this be so or not, the statement must involve some magnitude as a fundamental quantity, and this must be of such a character that, if it is not known, it can be readily referred to. We become familiar with the length of a mile by walking over distances expressed in miles, with the length of a yard or a foot by examining a yard or a foot measure and comparing it with something easily referred to, — say our own height, the length of our foot or step, — and similarly for quantities of other kinds. This leads us to be able to form a mental picture of such magnitudes when the numbers expressing them are stated, and hence to follow intelligently descriptions of the results of scientific work. The possession of copies of the units enables us by proper comparisons to find the magnitude-numbers expressing physical quantities for ourselves. The numbers descriptive of any quantity must depend on the intrinsic magnitude of the unit in terms of which it is described. Thus a mile is 1760 yards, or 5280 feet, and hence when a mile is taken as the unit the magnitude-number for the distance is 1, when a yard is taken as the unit the magnitude-number is 1760, and when a foot is taken it is 5280. Thus, to obtain the magnitude-number for a quantity in terms of a new unit when it is already known in terms of another we have to multiply the old magnitude-number by the ratio of the intrinsic values of the old and new units; that is, by the number of the new units required to make one of the old.

Fundamental Units of Length and Mass. — It is desirable that as few different kinds of unit quantities as possible should be introduced into our measurements, and since it has been found possible and convenient to express a large number of physical quantities in terms of length or mass or time units and combinations of these they have been very generally adopted as fundamental units. Two systems of such units are used in this country for scientific measurements, namely, the British, and the French or metric, systems. Tables of conversion factors are given in the book for facilitating comparisons between quantities expressed in terms of one system with similar quantities expressed in the other. In the customary system the standard unit of length is the yard and is now defined as 3600/3937 metre. The unit of mass is the avoirdupois pound and is defined as 1/2.20462 kilogramme.

The British yard is defined as the "straight line or distance (at 62° F.) between the transverse lines in the two gold plugs in the bronze bar deposited in the office of the exchequer." The British standard of mass is the pound avoirdupois and is the mass of a piece of platinum marked "P. S. 1844, 1 lb.," preserved in the exchequer office.

In the metric system the standard of length is defined as the distance between the ends of a certain platinum bar (the *mètre des Archives*) when the whole bar is at the temperature 0° Centigrade. The bar was made by Borda, and is preserved in the national archives of France. A line-standard metre has been constructed by the International Bureau of Weights and Measures, and is known as the International Prototype Metre. A number of standard-metre bars which have been carefully compared with the International Prototype have lately been made by the International Bureau of Weights and Measures and furnished to the various governments who have contributed to the support of that bureau. These copies are called National Prototypes.

Borda, Delambre, Laplace, and others, acting as a committee of the French Academy, recommended that the standard unit of length should be the ten millionth part of the length, from the equator to the pole, of the meridian passing through Paris. In 1795 the French Republic passed a decree making this the legal standard of length, and an arc of the meridian extending from Dunkirk to Barcelona was measured by Delambre and Mechain for the purpose of realizing the standard. From the results of that measurement the metre bar was made by Borda. The metre is not now defined as stated above, but as the length of Borda's rod, and hence subsequent measurements of the length of the meridian have not affected the length of the metre.

The French, or metric, standard of mass, the kilogramme, is the mass of a piece of platinum also made by Borda in accordance with the same decree of the Republic. It was connected with the standard of length by being made as nearly as possible of the same mass as that of a cubic decimetre of distilled water at the temperature of 4° C., or nearly the temperature of maximum density.

As in the case of the metre, the International Bureau of Weights and Measures has made copies of the kilogramme. One of these is taken as a standard, and

is called the International Prototype Kilogramme. The others were distributed in the same manner as the metre standards, and are called National Prototypes.

Comparisons of the French and customary standards are given in tabular form in Table 2; and similarly Table 3, differing slightly, compares the British and French systems. In the metric system the decimal subdivision is used, and thus we have the decimetre, the centimetre, and the millimetre as subdivisions, and the dekametre, hektometre, and kilometre as multiples. The centimetre is most commonly used in scientific work.

Time. — The unit of time in both the systems here referred to is the mean solar second, or the 86,400th part of the mean solar day. The unit of time is thus founded on the average time required for the earth to make one revolution on its axis relatively to the sun as a fixed point of reference.

Derived Units. — Units of quantities depending on powers greater than unity of the fundamental length, mass, and time units, or on combinations of different powers of these units, are called "derived units." Thus, the unit of area and of volume are respectively the area of a square whose side is the unit of length and the volume of a cube whose edge is the unit of length. Suppose that the area of a surface is expressed in terms of the foot as fundamental unit, and we wish to find the area-number when the yard is taken as fundamental unit. The yard is 3 times as long as the foot, and therefore the area of a square whose side is a yard is 3×3 times as great as that whose side is a foot. Thus, the surface will only make one ninth as many units of area when the yard is the unit of length as it will make when the foot is that unit. To transform, then, from the foot as old unit to the yard as new unit, we have to multiply the old area-number by 1/9, or by the ratio of the magnitude of the old to that of the new unit of area. This is the same rule as that given above, but it is usually more convenient to express the transformations in terms of the fundamental units directly. In the above case, since on the method of measurement here adopted an area-number is the product of a length-number by a length-number the ratio of two units is the square of the ratio of the intrinsic values of the two units of length. Hence, if l be the ratio of the magnitude of the old to that of the new unit of length, the ratio of the corresponding units of area is l^2. Similarly the ratio of two units of volume will be l^3, and so on for other quantities.

Dimensional Formulæ. — It is convenient to adopt symbols for the ratios of length units, mass units, and time units, and adhere to their use throughout; and in what follows, the small letters, l, m, t, will be used for these ratios. These letters will always represent simple numbers, but the magnitude of the number will depend on the relative magnitudes of the units the ratios of which they represent. When the values of the numbers represented by l, m, t are known, and the powers of l, m, and t involved in any particular unit are also known, the factor for transformation is at once obtained. Thus, in the above example, the value of l was 1/3 and the power of l involved in the expression for area is l^2; hence, the factor for transforming from square feet to square yards is 1/9. These factors

have been called by Prof. James Thomson "change ratios," which seems a appropriate term. The term "conversion factor" is perhaps more general known, and has been used throughout this book.

Conversion Factor. — In order to determine the symbolic expression for th conversion factor for any physical quantity, it is sufficient to determine the degr to which the quantities length, mass, and time are involved in the quantity. Thu a velocity is expressed by the ratio of the number representing a length to th representing an interval of time, or L/T, an acceleration by a velocity-numb divided by an interval of time-number, or L/T^2, and so on, and the correspon ing ratios of units must therefore enter to precisely the same degree. The fa tors would thus be for the above cases, l/t and l/t^2. Equations of the form abo given for velocity and acceleration which show the dimensions of the quantity terms of the fundamental units are called "dimensional equations." Thus

$$E = ML^2T^{-2}$$

is the dimensional equation for energy, and ML^2T^{-2} is the dimensional formu for energy.

In general, if we have an equation for a physical quantity

$$Q = CL^aM^bT^c,$$

where C is a constant and LMT represents length, mass, and time in terms of o set of units, and we wish to transform to another set of units in terms of whi the length, mass, and time are $L_1M_1T_1$, we have to find the value of $\frac{L_1}{L}, \frac{M_1}{M}, \frac{T_1}{T}$, whi in accordance with the convention adopted above will be $l\ m\ t$, or the ratios the magnitudes of the old to those of the new units.

Thus $L_1 = Ll$, $M_1 = Mm$, $T_1 = Tt$, and if Q_1 be the new quantity-number

$$\begin{aligned} Q_1 &= CL_1^aM_1^bT_1^c \\ &= CL^al^aM^bm^bT^ct^c = Ql^am^bt^c, \end{aligned}$$

or the conversion factor is $l^am^bt^c$, a quantity of precisely the same form as t dimension formula $L^aM^bT^c$.

We now proceed to form the dimensional and conversion factor formulæ f the more commonly occurring derived units.

1. **Area.** — The unit of area is the square the side of which is measured the unit of length. The area of a surface is therefore expressed as

$$S = CL^2,$$

where C is a constant depending on the shape of the boundary of the surfa and L a linear dimension. For example, if the surface be square and L be t length of a side C is unity. If the boundary be a circle and L be a diamet $C = \pi/4$, and so on. The dimensional formula is thus L^2, and the conversi factor l^2.

2. **Volume.** — The unit of volume is the volume of a cube the edge of whi is measured by the unit of length. The volume of a body is therefore expressed

$$V = CL^3,$$

where as before C is a constant depending on the shape of the boundary. The dimensional formula is L^3 and the conversion factor l^3.

3. **Density.** — The density of a substance is the quantity of matter in the unit of volume. The dimension formula is therefore M/V or ML^{-3}, and conversion factor ml^{-3}.

Example. — The density of a body is 150 in pounds per cubic foot: required the density in grains per cubic inch.

Here m is the number of grains in a pound = 7000, and l is the number of inches in a foot = 12; $\therefore ml^{-3} = 7000/12^3 = 4.051$. Hence the density is $150 \times 4.051 = 607.6$ in grains per cubic inch.

NOTE. — The specific gravity of a body is the ratio of its density to the density of a standard substance. The dimension formula and conversion factor are therefore both unity.

4. **Velocity.** — The velocity of a body at any instant is given by the equation $v = \frac{dL}{dT}$, or velocity is the ratio of a length-number to a time-number. The dimension formula is LT^{-1}, and the conversion factor lt^{-1}.

Example. — A train has a velocity of 60 miles an hour: what is its velocity in feet per second?

Here $l = 5280$ and $t = 3600$; $\therefore lt^{-1} = \frac{5280}{3600} = \frac{44}{30} = 1.467$. Hence the velocity $= 60 \times 1.467 = 88.0$ in feet per second.

5. **Angle.** — An angle is measured by the ratio of the length of an arc to the length of the radius of the arc. The dimension formula and the conversion factor are therefore both unity.

6. **Angular Velocity.** — Angular velocity is the ratio of the magnitude of the angle described in an interval of time to the length of the interval. The dimension formula is therefore T^{-1}, and the conversion factor is t^{-1}.

7. **Linear Acceleration.** — Acceleration is the rate of change of velocity or $a = \frac{dv}{dt}$. The dimension formula is therefore VT^{-1} or LT^{-2}, and the conversion factor is lt^{-2}.

Example: — A body acquires velocity at a uniform rate, and at the end of one minute is moving at the rate of 20 kilometres per hour: what is the acceleration in centimetres per second per second?

Since the velocity gained was 20 kilometres per hour in one minute, the acceleration was 1200 kilometres per hour per hour.

Here $l = 100\,000$ and $t = 3600$; $\therefore lt^{-2} = 100\,000/3600^2 = .00771$, and therefore acceleration $= .00771 \times 1200 = 9.26$ centimetres per second.

8. **Angular Acceleration.** — Angular acceleration is rate of change of angu-

lar velocity. The dimensional formula is thus $\frac{\text{angular velocity}}{T}$ or T^{-1}, and the conversion factor t^{-1}.

9. **Solid Angle.** — A solid angle is measured by the ratio of the surface of the portion of a sphere enclosed by the conical surface forming the angle to the square of radius of the spherical surface, the centre of the sphere being at the vertex of the cone. The dimensional formula is therefore $\frac{\text{area}}{L^2}$ or 1, and hence the conversion factor is also 1.

10. **Curvature.** — Curvature is measured by the rate of change of direction of the curve with reference to distance measured along the curve as independent variable. The dimension formula is therefore $\frac{\text{angle}}{\text{length}}$ or L^{-1}, and the conversion factor is l^{-1}.

11. **Tortuosity.** — Tortuosity is measured by the rate of rotation of the tangent plane round the tangent to the curve of reference when length along the curve is independent variable. The dimension formula is therefore $\frac{\text{angle}}{\text{length}}$ or L^{-1}, and the conversion factor is l^{-1}.

12. **Specific Curvature of a Surface.** — This was defined by Gauss to be, at any point of the surface, the ratio of the solid angle enclosed by a surface formed by moving a normal to the surface round the periphery of a small area containing the point, to the magnitude of the area. The dimensional formula is therefore $\frac{\text{solid angle}}{\text{surface}}$ or L^{-2}, and the conversion factor is thus l^{-2}.

13. **Momentum.** — This is quantity of motion in the Newtonian sense, and is, at any instant, measured by the product of the mass-number and the velocity-number for the body.

Thus the dimension formula is MV or MLT^{-1}, and the conversion factor mlt^{-1}.

Example. — A mass of 10 pounds is moving with a velocity of 30 feet per second: what is its momentum when the centimetre, the gramme, and the second are fundamental units?

Here $m = 453.59$, $l = 30.48$, and $t = 1$; $\therefore mlt^{-1} = 453.59 \times 30.48 = 13825$. The momentum is thus $13825 \times 10 \times 30 = 4\,147\,500$.

14. **Moment of Momentum.** — The moment of momentum of a body with reference to a point is the product of its momentum-number and the number expressing the distance of its line of motion from the point. The dimensional formula is thus ML^2T^{-1}, and hence the conversion factor is ml^2t^{-1}.

15. **Moment of Inertia.** — The moment of inertia of a body round any axis is expressed by the formula Σmr^2, where m is the mass of any particle of the body

and r its distance from the axis. The dimension formula for the sum is clearly the same as for each element, and hence is ML^2. The conversion factor is therefore ml^2.

16. **Angular Momentum.** — The angular momentum of a body round any axis is the product of the numbers expressing the moment of inertia and the angular velocity of the body. The dimensional formula and the conversion factor are therefore the same as for moment of momentum given above.

17. **Force.** — A force is measured by the rate of change of momentum it is capable of producing. The dimension formulæ for force and "time rate of change of momentum" are therefore the same, and are expressed by the ratio of momentum-number to time-number or MLT^{-2}. The conversion factor is thus mlt^{-2}.

NOTE. — When mass is expressed in pounds, length in feet, and time in seconds, the unit force is called the poundal. When grammes, centimetres, and seconds are the corresponding units the unit of force is called the dyne.

Example. Find the number of dynes in 25 poundals.

Here $m = 453.59$, $l = 30.48$, and $t = 1$; $\therefore mlt^{-2} = 453.59 \times 30.48 = 13825$ nearly. The number of dynes is thus $13825 \times 25 = 345625$ approximately.

18. **Moment of a Couple, Torque, or Twisting Motive.** — These are different names for a quantity which can be expressed as the product of two numbers representing a force and a length. The dimension formula is therefore FL or ML^2T^{-2}, and the conversion factor is ml^2t^{-2}.

19. **Intensity of a Stress.** — The intensity of a stress is the ratio of the number expressing the total stress to the number expressing the area over which the stress is distributed. The dimensional formula is thus FL^{-2} or $ML^{-1}T^{-2}$, and the conversion factor is $ml^{-1}t^{-2}$.

20. **Intensity of Attraction, or "Force at a Point."** — This is the force of attraction per unit mass on a body placed at the point, and the dimensional formula is therefore FM^{-1} or LT^{-2}, the same as acceleration. The conversion factors for acceleration therefore apply.

21. **Absolute Force of a Centre of Attraction, or "Strength of a Centre."** — This is the intensity of force at unit distance from the centre, and is therefore the force per unit mass at any point multiplied by the square of the distance from the centre. The dimensional formula thus becomes FL^2M^{-1} or L^3T^{-2}. The conversion factor is therefore l^3t^{-2}.

22. **Modulus of Elasticity.** — A modulus of elasticity is the ratio of stress intensity to percentage strain. The dimension of percentage strain is a length divided by a length, and is therefore unity. Hence, the dimensional formula of a modulus of elasticity is the same as that of stress intensity, or $ML^{-1}T^{-2}$, and the conversion factor is thus also $ml^{-1}t^{-2}$.

23. **Work and Energy.** — When the point of application of a force, acting on a body, moves in the direction of the force, work is done by the force, and the amount is measured by the product of the force and displacement numbers. The dimensional formula is therefore FL or ML^2T^{-2}.

The work done by the force either produces a change in the velocity of the body or a change of shape or configuration of the body, or both. In the first case it produces a change of kinetic energy, in the second a change of potential energy. The dimension formulæ of energy and work, representing quantities of the same kind, are identical, and the conversion factor for both is ml^2t^{-2}.

24. **Resilience.** — This is the work done per unit volume of a body in distorting it to the elastic limit or in producing rupture. The dimension formula is therefore $ML^2T^{-2}L^{-3}$ or $ML^{-1}T^{-2}$, and the conversion factor $ml^{-1}t^{-2}$.

25. **Power, or Activity.** — Power — or, as it is now very commonly called, activity — is defined as the time rate of doing work, or if W represent work and P power $P = \frac{dw}{dt}$. The dimensional formula is therefore WT^{-1} or ML^2T^{-3}, and the conversion factor ml^2t^{-3}, or for problems in gravitation units more conveniently flt^{-1}, where f stands for the force factor.

Examples. (*a*) Find the number of gramme centimetres in one foot pound.

Here the units of force are the attraction of the earth on the pound * and the gramme of matter, and the conversion factor is fl, where f is 453·59 and l is 30.48.

Hence the number is $453{\cdot}59 \times 30.48 = 13825$.

(*b*) Find the number of foot poundals in 1 000 000 centimetre dynes.

Here $m = 1/453{\cdot}59$, $l = 1/30.48$, and $t = 1$; $\therefore\ ml^2t^{-2} = 1/453{\cdot}59 \times 30.48^2$, and $10^6ml^2t^{-2} = 10^6/453{\cdot}59 \times 30.48^2 = 2.373$.

(*c*) If gravity produces an acceleration of 32.2 feet per second per second, how many watts are required to make one horse-power?

One horse-power is 550 foot pounds per second, or $550 \times 32.2 = 17710$ foot poundals per second. One watt is 10^7 ergs per second, that is, 10^7 dyne centimetres per second. The conversion factor is ml^2t^{-3}, where $m = 453{\cdot}59$, $l = 30.48$, and $t = 1$, and the result has to be divided by 10^7, the number of dyne centimetres per second in the watt.

Hence, $17710\ ml^2t^{-3}/10^7 = 17710 \times 453{\cdot}59 \times 30.48^2/10^7 = 746.3$.

(*d*) How many gramme centimetres per second correspond to 33000 foot pounds per minute?

The conversion factor suitable for this case is flt^{-1}, where f is 453·59, l is 30.48, and t is 60.

Hence, $33000\ lt^{-1} = 33000 \times 453{\cdot}59 \times 30.48/60 = 7\,604\,000$ nearly.

* It is important to remember that in problems like that here given the term "pound" or "gramme" refers to force and not to mass.

HEAT UNITS.

1. If heat be measured in dynamical units its dimensions are the same as those of energy, namely ML^2T^{-2}. The most common measurements, however, are made in thermal units, that is, in terms of the amount of heat required to raise the temperature of unit mass of water one degree of temperature at some stated temperature. This method of measurement involves the unit of mass and some unit of temperature; and hence, if we denote temperature-numbers by Θ and their conversion factors by θ, the dimensional formula and conversion factor for quantity of heat will be $M\Theta$ and $m\theta$ respectively. The relative amount of heat compared with water as standard substance required to raise unit mass of different substances one degree in temperature is called their specific heat, and is a simple number.

Unit volume is sometimes used instead of unit mass in the measurement of heat, the units being then called thermometric units. The dimensional formula is in that case changed by the substitution of volume for mass, and becomes $L^3\Theta$, and hence the conversion factor is to be calculated from the formula $l^3\theta$.

For other physical quantities involving heat we have:—

2. **Coefficient of Expansion.**—The coefficient of expansion of a substance is equal to the ratio of the change of length per unit length (linear), or change of volume per unit volume (voluminal) to the change of temperature. These ratios are simple numbers, and the change of temperature is inversely as the magnitude of the unit of temperature. Hence the dimensional and conversion-factor formulæ are Θ^{-1} and θ^{-1}.

3. **Conductivity, or Specific Conductance.**—This is the quantity of heat transmitted per unit of time per unit of surface per unit of temperature gradient. The equation for conductivity is therefore, with H as quantity of heat,

$$K = \frac{H}{\frac{\Theta}{L}L^2T}$$

and the dimensional formula $\frac{H}{\Theta LT} = \frac{M}{LT}$, which gives $ml^{-1}t^{-1}$ for conversion factor.

In thermometric units the formula becomes L^2T^{-1}, which properly represents diffusivity. In dynamical units H becomes ML^2T^{-2}, and the formula changes to $MLT^{-2}\Theta^{-1}$. The conversion factors obtained from these are l^2t^{-1} and $mlt^{-2}\theta^{-1}$ respectively.

4. Thermal Capacity. — This is the product of the number for mass and the specific heat, and hence the dimensional formula and conversion factor are simply M and m.

5. Latent Heat. — Latent heat is the ratio of the number representing the quantity of heat required to change the state of a body to the number representing the quantity of matter in the body. The dimensional formula is therefore $M\Theta/M$ or Θ, and hence the conversion factor is simply the ratio of the temperature units or θ. In dynamical units the factor is l^2t^{-2}.*

6. Joule's Equivalent. — Joule's dynamical equivalent is connected with quantity of heat by the equation

$$ML^2T^{-2} = JH \text{ or } JM\Theta.$$

This gives for the dimensional formula of J the expression $L^2T^{-2}\Theta^{-1}$. The conversion factor is thus represented by $l^2t^{-2}\theta^{-1}$. When heat is measured in dynamical units J is a simple number.

7. Entropy. — The entropy of a body is directly proportional to the quantity of heat it contains and inversely proportional to its temperature. The dimensional formula is thus $M\Theta/\Theta$ or M, and the conversion factor is m. When heat is measured in dynamical units the factor is $ml^2t^{-2}\theta^{-1}$.

Examples. (*a*) Find the relation between the British thermal unit, the calorie, and the therm.

Neglecting the variation of the specific heat of water with temperature, or defining all the units for the same temperature of the standard substance, we have the following definitions. The *British thermal unit* is the quantity of heat required to raise the temperature of one pound of water 1° F. The *calorie* is the quantity of heat required to raise the temperature of one kilogramme of water 1° C. The *therm* is the quantity of heat required to raise the temperature of one gramme of water 1° C. Hence: —

(1) To find the number of calories in one British thermal unit, we have $m = .45399$ and $\theta = \frac{5}{9}$; $\therefore m\theta = .45399 \times 5/9 = .25199$.

(2) To find the number of therms in one calorie, $m = 1000$ and $\theta = 1$; $\therefore m\theta = 1000$.

It follows at once that the number of therms in one British thermal unit is $1000 \times .25199 = 251.99$.

(*b*) What is the relation between the foot grain second Fahrenheit-degree and the centimetre gramme second Centigrade-degree units of conductivity?

The number of the latter units in one of the former is given by the for-

* It will be noticed that when Θ is given the dimension formula L^2T^{-2} the formulæ in thermal and dynamical units are always identical. The thermometric units practically suppress mass.

mula $ml^{-1}t^{-1}\theta^{\circ}$, where $m = .064799$, $l = 30.48$, and $t = 1$, and is therefore $= .064799/30.48 = 2.126 \times 10^{-3}$.

(*c*) Find the relation between the units stated in (*b*) for emissivity.

In this case the conversion formula is $ml^{-2}t^{-1}$, where ml and t have the same value as before. Hence the number of the latter units in the former is $0.064799/30.48^2 = 6.975 \times 10^{-5}$.

(*d*) Find the number of centimetre gramme second units in the inch grain hour unit of emissivity.

Here the formula is $ml^{-2}t^{-1}$, where $m = 0.064799$, $l = 2.54$, and $t = 3600$. Therefore the required number is $0.064799/2.54^2 \times 3600 = 2.790 \times 10^{-6}$.

(*e*) If Joule's equivalent be 776 foot pounds per pound of water per degree Fahrenheit, what will be its value in gravitation units when the metre, the kilogramme, and the degree Centigrade are units?

The conversion factor in this case is $\frac{l^2t^{-2}\theta^{-1}}{lt^{-2}}$ or $l\theta^{-1}$, where $l = .3048$ and $\theta^{-1} = 1.8$; $\therefore 776 \times .3048 \times 1.8 = 425.7$.

(*f*) If Joule's equivalent be 24832 foot poundals when the degree Fahrenheit is unit of temperature, what will be its value when kilogramme metre second and degree-Centigrade units are used?

The conversion factor is $l^2t^{-2}\theta^{-1}$, where $l = .3048$, $t = 1$, and $\theta^{-1} = 1.8$; $\therefore 24832 \times l^2t^{-2}\theta^{-1} = 24832 \times .3048^2 \times 1.8 = 4152.5$.

In gravitation units this would give $4152.5/9.81 = 423.3$.

ELECTRIC AND MAGNETIC UNITS.

There are two systems of these units, the electrostatic and the electromagnetic systems, which differ from each other because of the different fundamental suppositions on which they are based. In the electrostatic system the repulsive force between two quantities of static electricity is made the basis. This connects force, quantity of electricity, and length by the equation $f = a\frac{qq_1}{l^2}$, where f is force, a a quantity depending on the units employed and on the nature of the medium, q and q_1 quantities of electricity, and l the distance between q and q_1. The magnitude of the force f for any particular values of q, q_1 and l depends on a property of the medium across which the force takes place called its inductive capacity. The inductive capacity of air has generally been assumed as unity, and the inductive capacity of other media expressed as a number representing the ratio of the inductive capacity of the medium to that of air. These numbers are known as the specific inductive capacities of the media. According to the ordinary assumption, then, of air as the standard medium, we obtain unit quantity of electricity when in the above equation $q = q_1$, and f, a, and l are each unity. A formal definition is given below.

In the electromagnetic system the repulsion between two magnetic poles or

quantities of magnetism is taken as the basis. In this system the quantities force, quantity of magnetism, and length are connected by an equation of the form

$$f = a\frac{mm_1}{l^2},$$

where m and m_1 are in this case quantities of magnetism, and the other symbols have the same meaning as before. In this case it has been usual to assume the magnetic inductive capacity of air to be unity, and to express the magnetic inductive capacity of other media as a simple number representing the ratio of the inductive capacity of the medium to that of air. These numbers, by analogy with specific inductive capacity for electricity, might be called specific inductive capacities for magnetism. They are usually called permeabilities. (*Vide* Thomson, "Papers on Electrostatics and Magnetism," p. 484.) In this case, also, like that for electricity, the unit quantity of magnetism is obtained by making $m = m_1$, and f, a, and l each unity.

In both these cases the intrinsic inductive capacity of the standard medium is suppressed, and hence also that of all other media. Whether this be done or not, direct experiment has to be resorted to for the determination of the absolute values of the units and the relations of the units in the one system to those in the other. The character of this relation can be directly inferred from the dimensional formulæ of the different quantities, but these can give no information as to the relative absolute values of the units in the two systems. Prof. Rücker has suggested (Phil. Mag. vol. 27) the advisability of at least indicating the existence of the suppressed properties by putting symbols for them in the dimensional formulæ. This has the advantage of showing how the magnitudes of the different units would be affected by a change in the standard medium, or by making the standard medium different for the two systems. In accordance with this idea, the symbols K and P have been introduced into the formulæ given below to represent inductive capacity in the electrostatic and the electromagnetic systems respectively. In the conversion formulæ k and p are the ordinary specific inductive capacities and permeabilities of the media when air is taken as the standard, or generally those with reference to the first medium taken as standard. The ordinary formulæ may be obtained by putting K and P equal to unity.

ELECTROSTATIC UNITS.

1. **Quantity of Electricity.** — The unit quantity of electricity is defined as that quantity which if concentrated at a point and placed at unit distance from an equal and similarly concentrated quantity repels it, or is repelled by it, with unit force. The medium or dielectric is usually taken as air, and the other units in accordance with the centimetre gramme second system.

In this case we have the force of repulsion proportional directly to the square of the quantity of electricity and inversely to the square of the distance between the quantities and to the inductive capacity. The dimensional formula is therefore the same as that for [force $\times$ length^2 $\times$ inductive capacity]$^{\frac{1}{2}}$ or $M^{\frac{1}{2}}L^{\frac{1}{2}}T^{-1}K^{\frac{1}{2}}$, and the conversion factor is $m^{\frac{1}{2}}l^{\frac{1}{2}}t^{-1}k^{\frac{1}{2}}$.

2. **Electric Surface Density and Electric Displacement.** — The density of an electric distribution at any point on a surface is measured by the quantity per unit of area, and the electric displacement at any point in a dielectric is measured by the quantity displaced per unit of area. These quantities have therefore the same dimensional formula, namely, the ratio of the formulæ for quantity of electricity and for area or $M^{\frac{1}{2}}L^{-\frac{1}{2}}T^{-1}K^{\frac{1}{2}}$, and the conversion factor $m^{\frac{1}{2}}l^{-\frac{1}{2}}t^{-1}k^{\frac{1}{2}}$.

3. **Electric Force at a Point, or Intensity of Electric Field.** — This is measured by the ratio of the magnitude of the force on a quantity of electricity at a point to the magnitude of the quantity of electricity. The dimensional formula is therefore the ratio of the formulæ for force and electric quantity, or

$$\frac{MLT^{-2}}{M^{\frac{1}{2}}L^{\frac{1}{2}}T^{-1}K^{\frac{1}{2}}} = M^{\frac{1}{2}}L^{-\frac{1}{2}}T^{-1}K^{-\frac{1}{2}},$$

which gives the conversion factor $m^{\frac{1}{2}}l^{-\frac{1}{2}}t^{-1}k^{-\frac{1}{2}}$.

4. **Electric Potential and Electromotive Force.** — Change of potential is proportional to the work done per unit of electricity in producing the change. The dimensional formula is therefore the ratio of the formulæ for work and electric quantity, or

$$\frac{ML^2T^{-2}}{M^{\frac{1}{2}}L^{\frac{1}{2}}T^{-1}K^{\frac{1}{2}}} = M^{\frac{1}{2}}L^{\frac{1}{2}}T^{-1}K^{-\frac{1}{2}},$$

which gives the conversion factor $m^{\frac{1}{2}}l^{\frac{1}{2}}t^{-1}k^{-\frac{1}{2}}$.

5. **Capacity of a Conductor.** — The capacity of an insulated conductor is proportional to the ratio of the numbers representing the quantity of electricity in a charge and the potential of the charge. The dimensional formula is thus the ratio of the two formulæ for electric quantity and potential, or

$$\frac{M^{\frac{1}{2}}L^{\frac{1}{2}}T^{-1}K^{\frac{1}{2}}}{M^{\frac{1}{2}}L^{\frac{1}{2}}T^{-1}K^{-\frac{1}{2}}} = LK,$$

which gives lk for conversion factor. When K is taken as unity, as in the ordinary units, the capacity of an insulated conductor is simply a length.

6. **Specific Inductive Capacity.** — This is the ratio of the inductive capacity of the substance to that of a standard substance, and hence the dimensional formula is K/K or 1.*

7. **Electric Current.** — Current is quantity flowing past a point per unit of time. The dimensional formula is thus the ratio of the formulæ for electric quantity and for time, or

$$\frac{M^{\frac{1}{2}}L^{\frac{1}{2}}T^{-1}K^{\frac{1}{2}}}{T} = M^{\frac{1}{2}}L^{\frac{1}{2}}T^{-2}K^{\frac{1}{2}},$$

and the conversion factor $m^{\frac{1}{2}}l^{\frac{1}{2}}t^{-2}k^{\frac{1}{2}}$.

* According to the ordinary definition referred to air as standard medium, the specific inductive capacity of a substance is K, or is identical in dimensions with what is here taken as inductive capacity. Hence in that case the conversion factor must be taken as 1 on the electrostatic and as $l^{-2}t^2$ on the electromagnetic system.

8. **Conductivity, or Specific* Conductance.** — This, like the corresponding term for heat, is quantity per unit area per unit potential gradient per unit of time. The dimensional formula is therefore

$$\frac{M^{\frac{1}{2}}L^{\frac{1}{2}}T^{-1}K^{\frac{1}{2}}}{L^2\frac{M^{\frac{1}{2}}L^{\frac{1}{2}}T^{-1}K^{-\frac{1}{2}}}{L}T} = T^{-1}K, \text{ or } \frac{\text{electric quantity}}{\text{area} \times \text{potential gradient} \times \text{time}}.$$

The conversion factor is $t^{-1}k$.

9. **Specific* Resistance.** — This is the reciprocal of conductivity as above defined, and hence the dimensional formula and conversion factor are respectively TK^{-1} and tk^{-1}.

10. **Conductance.** — The conductance of any part of an electric circuit, not containing a source of electromotive force, is the ratio of the numbers representing the current flowing through it and the difference of potential between its ends. The dimensional formula is thus the ratio of the formulæ for current and potential, or

$$\frac{M^{\frac{1}{2}}L^{\frac{1}{2}}T^{-2}K^{\frac{1}{2}}}{M^{\frac{1}{2}}L^{\frac{1}{2}}T^{-1}K^{-\frac{1}{2}}} = LT^{-1}K,$$

from which we get the conversion factor $lt^{-1}k$.

11. **Resistance.**—This is the reciprocal of conductance, and therefore the dimensional formula and the conversion factor are respectively $L^{-1}TK^{-1}$ and $l^{-1}tk^{-1}$.

EXAMPLES OF CONVERSION IN ELECTROSTATIC UNITS.

(*a*) Find the factor for converting quantity of electricity expressed in foot grain second units to the same expressed in c. g. s. units.

By (1) the formula is $m^{\frac{1}{2}}l^{\frac{1}{2}}t^{-1}k^{\frac{1}{2}}$, in which in this case $m = 0.0648$, $l = 30.48$, $t = 1$, and $k = 1$; $\therefore$ the factor is $0.0648^{\frac{1}{2}} \times 30.48^{\frac{1}{2}} = 4.2836$.

(*b*) Find the factor required to convert electric potential from millimetre milligramme second units to c. g. s. units.

By (4) the formula is $m^{\frac{1}{2}}l^{\frac{1}{2}}t^{-1}k^{-\frac{1}{2}}$, and in this case $m = 0.001$, $l = 0.1$, $t = 1$, and $k = 1$; $\therefore$ the factor $= 0.001^{\frac{1}{2}} \times 0.1^{\frac{1}{2}} = 0.01$.

(*c*) Find the factor required to convert from foot grain second and specific inductive capacity 6 units to c. g. s. units.

By (5) the formula is lk, and in this case $l = 30.48$ and $k = 6$; $\therefore$ the factor $= 30.48 \times 6 = 182.88$.

* The term "specific," as used here and in 9, refers conductance and resistance to that between the ends of a bar of unit section and unit length, and hence is different from the same term in specific heat, specific inductivity, capacity, etc., which refer to a standard substance.

ELECTROMAGNETIC UNITS.

As stated above, these units bear the same relation to unit quantity of magnetism that the electric units do to quantity of electricity. Thus, when inductive capacity is suppressed, the dimensional formula for magnetic quantity on this system is the same as that for electric quantity on the electrostatic system. All quantities in this system which only differ from corresponding quantities defined above by the substitution of magnetic for electric quantity may have their dimensional formulæ derived from those of the corresponding quantity by substituting P for K.

1. **Magnetic Pole, or Quantity of Magnetism.** — Two unit quantities of magnetism concentrated at points unit distance apart repel each other with unit force. The dimensional formula is thus the same as for [force $\times$ length^2 $\times$ inductive capacity] or $M^{\frac{1}{2}}L^{\frac{3}{2}}T^{-1}P^{\frac{1}{2}}$, and the conversion factor is $m^{\frac{1}{2}}l^{\frac{3}{2}}t^{-1}p^{\frac{1}{2}}$.

2. **Density of Surface Distribution of Magnetism.** — This is measured by quantity of magnetism per unit area, and the dimension formula is therefore the ratio of the expressions for magnetic quantity and for area, or $M^{\frac{1}{2}}L^{-\frac{1}{2}}T^{-1}P^{\frac{1}{2}}$, which gives the conversion factor $m^{\frac{1}{2}}l^{-\frac{1}{2}}t^{-1}p^{\frac{1}{2}}$.

3. **Magnetic Force at a Point, or Intensity of Magnetic Field.** — The number for this is the ratio of the numbers representing the magnitudes of the force on a magnetic pole placed at the point and the magnitude of the magnetic pole.

The dimensional formula is therefore the ratio of the expressions for force and magnetic quantity, or

$$\frac{MLT^{-2}}{M^{\frac{1}{2}}L^{\frac{3}{2}}T^{-1}P^{\frac{1}{2}}} = M^{\frac{1}{2}}L^{-\frac{1}{2}}T^{-1}P^{-\frac{1}{2}},$$

and the conversion factor $m^{\frac{1}{2}}l^{-\frac{1}{2}}t^{-1}p^{-\frac{1}{2}}$.

4. **Magnetic Potential.** — The magnetic potential at a point is measured by the work which is required to bring unit quantity of positive magnetism from zero potential to the point. The dimensional formula is thus the ratio of the formula for work and magnetic quantity, or

$$\frac{ML^2T^{-2}}{M^{\frac{1}{2}}L^{\frac{3}{2}}T^{-1}P^{\frac{1}{2}}} = M^{\frac{1}{2}}L^{\frac{1}{2}}T^{-1}P^{-\frac{1}{2}},$$

which gives the conversion factor $m^{\frac{1}{2}}l^{\frac{1}{2}}t^{-1}p^{-\frac{1}{2}}$.

5. **Magnetic Moment.** — This is the product of the numbers for pole strength and length of a magnet. The dimensional formula is therefore the product of the formulæ for magnetic quantity and length, or $M^{\frac{1}{2}}L^{\frac{3}{2}}T^{-1}P^{\frac{1}{2}}$, and the conversion factor $m^{\frac{1}{2}}l^{\frac{3}{2}}t^{-1}p^{\frac{1}{2}}$.

6. **Intensity of Magnetization.** — The intensity of magnetization of any portion of a magnetized body is the ratio of the numbers representing the magni-

tude of the magnetic moment of that portion and its volume. The dimensional formula is therefore the ratio of the formulæ for magnetic moment and volume, or

$$\frac{M^{\frac{1}{2}}L^{\frac{1}{2}}T^{-1}P^{\frac{1}{2}}}{L^3} = M^{\frac{1}{2}}L^{-\frac{5}{2}}T^{-1}P^{\frac{1}{2}}.$$

The conversion factor is therefore $m^{\frac{1}{2}}l^{-\frac{5}{2}}t^{-1}p^{\frac{1}{2}}$.

7. **Magnetic Permeability,* or Specific Magnetic Inductive Capacity.** — This is the analogue in magnetism to specific inductive capacity in electricity. It is the ratio of the magnetic induction in the substance to the magnetic induction in the field which produces the magnetization, and therefore its dimensional formula and conversion factor are unity.

8. **Magnetic Susceptibility.** — This is the ratio of the numbers which represent the values of the intensity of magnetization produced and the intensity of the magnetic field producing it. The dimensional formula is therefore the ratio of the formulæ for intensity of magnetization and magnetic field or

$$\frac{M^{\frac{1}{2}}L^{-\frac{1}{2}}T^{-1}P^{\frac{1}{2}}}{M^{\frac{1}{2}}L^{-\frac{1}{2}}T^{-1}P^{-\frac{1}{2}}} \text{ or } P.$$

The conversion factor is therefore p, and both the dimensional formula and conversion factor are unity in the ordinary system.

9. **Current Strength.** — A current of strength c flowing round a circle of radius r produces a magnetic field at the centre of intensity $2\pi c/r$. The dimensional formula is therefore the product of the formulæ for magnetic field intensity and length, or $M^{\frac{1}{2}}L^{\frac{1}{2}}T^{-1}P^{-\frac{1}{2}}$, which gives the conversion factor $m^{\frac{1}{2}}l^{\frac{1}{2}}t^{-1}p^{-\frac{1}{2}}$.

10. **Current Density, or Strength of Current at a Point.** — This is the ratio of the numbers for current strength and area. The dimensional formula and the conversion factor are therefore $M^{\frac{1}{2}}L^{-\frac{3}{2}}T^{-1}P^{-\frac{1}{2}}$ and $m^{\frac{1}{2}}l^{-\frac{3}{2}}t^{-1}p^{-\frac{1}{2}}$.

11. **Quantity of Electricity.** — This is the product of the numbers for current and time. The dimensional formula is therefore $M^{\frac{1}{2}}L^{\frac{1}{2}}T^{-1}P^{-\frac{1}{2}} \times T = M^{\frac{1}{2}}L^{\frac{1}{2}}P^{-\frac{1}{2}}$, and the conversion factor $m^{\frac{1}{2}}l^{\frac{1}{2}}p^{-\frac{1}{2}}$.

12. **Electric Potential, or Electromotive Force.** — As in the electrostatic system, this is the ratio of the numbers for work and quantity of electricity. The dimensional formula is therefore

$$\frac{ML^2T^{-2}}{M^{\frac{1}{2}}L^{\frac{1}{2}}P^{-\frac{1}{2}}} = M^{\frac{1}{2}}L^{\frac{3}{2}}T^{-2}P^{\frac{1}{2}},$$

and the conversion factor $m^{\frac{1}{2}}l^{\frac{3}{2}}t^{-2}p^{\frac{1}{2}}$.

* Permeability, as ordinarily taken with the standard medium as unity, has the same dimension formula and conversion factor as that which is here taken as magnetic inductive capacity. Hence for ordinary transformations the conversion factor should be taken as 1 in the electromagnetic and $l^{-2}t^2$ in the electrostatic systems.

13. **Electrostatic Capacity.** — This is the ratio of the numbers for quantity of electricity and difference of potential. The dimensional formula is therefore

$$\frac{M^{\frac{1}{2}}L^{\frac{1}{2}}P^{-\frac{1}{2}}}{M^{\frac{1}{2}}L^{\frac{1}{2}}T^{-2}P^{\frac{1}{2}}} = L^{-1}T^{2}P^{-1},$$

and the conversion factor $l^{-1}t^{2}p^{-1}$.

14. **Resistance of a Conductor.** — The resistance of a conductor or electrode is the ratio of the numbers for difference of potential between its ends and the constant current it is capable of producing. The dimensional formula is therefore the ratio of those for potential and current or

$$\frac{M^{\frac{1}{2}}L^{\frac{1}{2}}T^{-2}P^{\frac{1}{2}}}{M^{\frac{1}{2}}L^{\frac{1}{2}}T^{-1}P^{-\frac{1}{2}}} = LT^{-1}P.$$

The conversion factor thus becomes $lt^{-1}p$, and in the ordinary system resistance has the same conversion factor as velocity.

15. **Conductance.** — This is the reciprocal of resistance, and hence the dimensional formula and conversion factor are respectively $L^{-1}TP^{-1}$ and $l^{-1}tp^{-1}$.

16. **Conductivity, or Specific Conductance.** — This is quantity of electricity transmitted per unit of area per unit of potential gradient per unit of time. The dimensional formula is therefore derived from those of the quantities mentioned as follows: —

$$\frac{M^{\frac{1}{2}}L^{\frac{1}{2}}P^{-\frac{1}{2}}}{L^{2}\dfrac{M^{\frac{1}{2}}L^{\frac{1}{2}}T^{-2}P^{\frac{1}{2}}}{L}T} = L^{-2}TP^{-1}.$$

The conversion factor is therefore $l^{-2}tp^{-1}$.

17. **Specific Resistance.** — This is the reciprocal of conductivity as defined in 16, and hence the dimensional formula and conversion factor are respectively $L^{2}T^{-1}P$ and $l^{2}t^{-1}p$.

18. **Coefficient of Self-Induction, or Inductance, or Electro-kinetic Inertia.** — These are for any circuit the electromotive force produced in it by unit rate of variation of the current through it. The dimensional formula is therefore the product of the formulæ for electromotive force and time divided by that for current or

$$\frac{M^{\frac{1}{2}}L^{\frac{1}{2}}T^{-2}P^{\frac{1}{2}}}{M^{\frac{1}{2}}L^{\frac{1}{2}}T^{-1}P^{-\frac{1}{2}}} \times T = LP.$$

The conversion factor is therefore lp, and in the ordinary system is the same as that for length.

19. **Coefficient of Mutual Induction.** — The mutual induction of two circuits is the electromotive force produced in one per unit rate of variation of the current in the other. The dimensional formula and the conversion factor are therefore the same as those for self-induction.

20. **Electro-kinetic Momentum.**—The number for this is the product of the numbers for current and for electro-kinetic inertia. The dimensional formula is therefore the product of the formulæ for these quantities, or $M^{\frac{1}{2}}L^{\frac{1}{2}}T^{-1}P^{-\frac{1}{2}} \times LP = M^{\frac{1}{2}}L^{\frac{1}{2}}T^{-1}P^{\frac{1}{2}}$, and the conversion factor $m^{\frac{1}{2}}l^{\frac{1}{2}}t^{-1}p^{\frac{1}{2}}$.

21. **Electromotive Force at a Point.**—The number for this quantity is the ratio of the numbers for electric potential or electromotive force as given in 12, and for length. The dimensional formula is therefore $M^{\frac{1}{2}}L^{\frac{1}{2}}T^{-2}P^{\frac{1}{2}}$, and the conversion factor $m^{\frac{1}{2}}l^{\frac{1}{2}}t^{-2}p^{\frac{1}{2}}$.

22. **Vector Potential.**—This is time integral of electromotive force at a point, or the electro-kinetic momentum at a point. The dimensional formula may therefore be derived from 21 by multiplying by T, or from 20 by dividing by L. It is therefore $M^{\frac{1}{2}}L^{\frac{1}{2}}T^{-1}P^{\frac{1}{2}}$, and the conversion factor $m^{\frac{1}{2}}l^{\frac{1}{2}}t^{-1}p^{\frac{1}{2}}$.

23. **Thermoelectric Height.**—This is measured by the ratio of the numbers for electromotive force and for temperature. The dimensional formula is therefore the ratio of the formulæ for these two quantities, or $M^{\frac{1}{2}}L^{\frac{1}{2}}T^{-2}P^{\frac{1}{2}}\Theta^{-1}$, and the conversion factor $m^{\frac{1}{2}}l^{\frac{1}{2}}t^{-2}p^{\frac{1}{2}}\theta^{-1}$.

24. **Specific Heat of Electricity.**—This quantity is measured in the same way as 23, and hence has the same formulæ.

25. **Coefficient of Peltier Effect.**—This is measured by the ratio of the numbers for quantity of heat and for quantity of electricity. The dimensional formula is therefore

$$\frac{M\Theta}{M^{\frac{1}{2}}L^{\frac{1}{2}}P^{-\frac{1}{2}}} = M^{\frac{1}{2}}L^{-\frac{1}{2}}P^{\frac{1}{2}}\Theta,$$

and the conversion factor $m^{\frac{1}{2}}l^{-\frac{1}{2}}p^{\frac{1}{2}}\theta$.

EXAMPLES OF CONVERSION IN ELECTROMAGNETIC UNITS.

(*a*) Find the factor required to convert intensity of magnetic field from foot grain minute units to c. g. s. units.

By (3) the formula is $m^{\frac{1}{2}}l^{-\frac{1}{2}}t^{-1}p^{-\frac{1}{2}}$, and in this case $m = 0.0648$, $l = 30.48$, $t = 60$, and $p = 1$; $\therefore$ the factors $= 0.0648^{\frac{1}{2}} \times 30.48^{-\frac{1}{2}} \times 60^{-1} = 0.00076847$.

Similarly to convert from foot grain second units to c. g. s. units the factor is $0.0648^{\frac{1}{2}} \times 30.48^{-\frac{1}{2}} = 0.046108$.

(*b*) How many c. g. s. units of magnetic moment make one foot grain second unit of the same quantity?

By (5) the formula is $m^{\frac{1}{2}}l^{\frac{1}{2}}t^{-1}p^{\frac{1}{2}}$, and the values for this problem are $m = 0.0648$, $l = 30.48$, $t = 1$, and $p = 1$; $\therefore$ the number $= 0.0648^{\frac{1}{2}} \times 30.48^{\frac{1}{2}} = 1305.6$.

tensity of magnetization of a steel bar be 700 in c. g. s. units, what illimetre milligramme second units?

By (6) the formula is $m^{\frac{1}{2}}l^{\frac{3}{2}}t^{-1}p^{\frac{1}{2}}$, and in this case $m = 1000$, $l = 10$, $t = 1$, and $p = 1$; $\therefore$ the intensity $= 700 \times 1000^{\frac{1}{2}} \times 10^{\frac{3}{2}} = 70000$.

(*d*) Find the factor required to convert current strength from c. g. s. units to earth quadrant 10^{-11} gramme and second units.

By (9) the formula is $m^{\frac{1}{2}}l^{\frac{1}{2}}t^{-1}p^{-\frac{1}{2}}$, and the values of these quantities are here $m = 10^{11}$, $l = 10^{-9}$, $t = 1$, and $p = 1$; $\therefore$ the factor $= 10^{\frac{11}{2}} \times 10^{-\frac{9}{2}} = 10$.

(*e*) Find the factor required to convert resistance expressed in c. g. s. units into the same expressed in earth-quadrant 10^{-11} grammes and second units.

By (14) the formula is $lt^{-1}p$, and for this case $l = 10^{-9}$, $t = 1$, and $p = 1$; $\therefore$ the factor $= 10^{-9}$.

(*f*) Find the factor required to convert electromotive force from earth-quadrant 10^{-11} gramme and second units to c. g. s. units.

By (12) the formula is $m^{\frac{1}{2}}l^{\frac{1}{2}}t^{-2}p^{1}$, and for this case $m = 10^{-11}$, $l = 10^{9}$, $t = 1$, and $p = 1$; $\therefore$ the factor $= 10^{8}$.

PRACTICAL UNITS.

In practical electrical measurements the units adopted are either multiples or submultiples of the units founded on the centimetre, the gramme, and the second as fundamental units, and air is taken as the standard medium, for which K and P are assumed unity. The following, quoted from the report to the Honorable the Secretary of State, under date of November 6th, 1893, by the delegates representing the United States, gives the ordinary units with their names and values as defined by the International Congress at Chicago in 1893: —

"*Resolved*, That the several governments represented by the delegates of this International Congress of Electricians be, and they are hereby, recommended to formally adopt as legal units of electrical measure the following: As a unit of resistance, the *international ohm*, which is based upon the ohm equal to 10^9 units of resistance of the C. G. S. system of electro-magnetic units, and is represented by the resistance offered to an unvarying electric current by a column of mercury at the temperature of melting ice 14.4521 grammes in mass, of a constant cross-sectional area and of the length of 106.3 centimetres.

"As a unit of current, the *international ampère*, which is one tenth of the unit of current of the C. G. S. system of electro-magnetic units, and which is represented sufficiently well for practical use by the unvarying current which, when passed through a solution of nitrate of silver in water, and in accordance with accompanying specifications,* deposits silver at the rate of 0.001118 of a gramme per second.

* "In the following specification the term 'silver voltameter' means the arrangement of apparatus by means of which an electric current is passed through a solution of nitrate of silver in water. The silver voltameter measures the total electrical quantity which has passed during the time of the experiment, and by noting this time the time average of the current, or, if the current has been kept constant, the current itself can be deduced.

"In employing the silver voltameter to measure currents of about one ampère, the following arrangements should be adopted: —

"As a unit of electromotive force, the *international volt*, which is the electromotive force that, steadily applied to a conductor whose resistance is one international ohm, will produce a current of one international ampère, and which is represented sufficiently well for practical use by $\frac{1000}{1434}$ of the electromotive force between the poles or electrodes of the voltaic cell known as Clark's cell, at a temperature of 15° C., and prepared in the manner described in the accompanying specification.*

"As a unit of quantity, the *international coulomb*, which is the quantity of electricity transferred by a current of one international ampère in one second.

"As a unit of capacity, the *international farad*, which is the capacity of a condenser charged to a potential of one international volt by one international coulomb of electricity.†

"As a unit of work, the *joule*, which is equal to 10^7 units of work in the c. g. s. system, and which is represented sufficiently well for practical use by the energy expended in one second by an international ampère in an international ohm.

"As a unit of power, the *watt*, which is equal to 10^7 units of power in the c. g. s. system, and which is represented sufficiently well for practical use by the work done at the rate of one joule per second.

"As the unit of induction, the *henry*, which is the induction in a circuit when the electromotive force induced in this circuit is one international volt, while the inducing current varies at the rate of one ampère per second.

"The Chamber also voted that it was not wise to adopt or recommend a standard of light at the present time."

By an Act of Congress approved July 12th, 1894, the units recommended by the Chicago Congress were adopted in this country with only some unimportant verbal changes in the definitions.

By an Order in Council of date August 23d, 1894, the British Board of Trade adopted the ohm, the ampere, and the volt, substantially as recommended by the Chicago Congress. The other units were not legalized in Great Britain. They are, however, in general use in that country and all over the world.

"The kathode on which the silver is to be deposited should take the form of a platinum bowl not less than 10 centimetres in diameter and from 4 to 5 centimetres in depth.

"The anode should be a plate of pure silver some 30 square centimetres in area and 2 or 3 millimetres in thickness.

"This is supported horizontally in the liquid near the top of the solution by a platinum wire passed through holes in the plate at opposite corners. To prevent the disintegrated silver which is formed on the anode from falling on to the kathode, the anode should be wrapped round with pure filter paper, secured at the back with sealing wax.

"The liquid should consist of a neutral solution of pure silver nitrate, containing about 15 parts by weight of the nitrate to 85 parts of water.

"The resistance of the voltameter changes somewhat as the current passes. To prevent these changes having too great an effect on the current, some resistance besides that of the voltameter should be inserted in the circuit. The total metallic resistance of the circuit should not be less than 10 ohms."

* A committee, consisting of Messrs. Helmholtz, Ayrton, and Carhart, was appointed to prepare specifications for the Clark's cell, but no report was made, on account of Helmholtz's death.

† The one millionth part of the farad is more commonly used in practical measurements, and is called the microfarad.

Smithsonian Libraries

PHYSICAL TABLES

TABLE 1.

FUNDAMENTAL AND DERIVED UNITS.

To change a quantity from one system of units to another: substitute in the corresponding conversion factor from the following table the ratio of the magnitudes of the *old* units to the *new* and multiply the old quantity by the resulting number. For example: to reduce velocity in miles per hour to feet per second, the conversion factor is $l\,t^{-1}$; $l=5280/1$, $t=3600/1$, therefore the factor $=5280/3600=1.467$.

(*a*) FUNDAMENTAL UNITS.

Name of Unit.	Symbol.	Conversion Factor.
Length.	L	l
Mass.	M	m
Time.	T	t
Temperature.	Θ	θ
Electric Inductive Capacity.	K	k
Magnetic Inductive Capacity.	P	p

(*b*) DERIVED UNITS.

I. Geometric and Dynamic Units.

Name of Unit.	Conversion Factor.
Area.	l^2
Volume.	l^3
Angle.	1
Solid Angle.	1
Curvature.	l^{-1}
Tortuosity.	l^{-1}
Specific curvature of a surface.	l^{-2}
Angular velocity.	t^{-1}
Angular acceleration.	t^{-2}
Linear velocity.	$l\,t^{-1}$
Linear acceleration.	$l\,t^{-2}$
Density.	$m\,l^{-3}$
Moment of inertia.	$m\,l^2$
Intensity of attraction, or "force at a point."	$l\,t^{-2}$
Absolute force of a centre of attraction, or "strength of a centre."	$l^3\,t^{-2}$
Momentum.	$m\,l\,t^{-1}$
Moment of momentum, or angular momentum.	$m\,l^2\,t^{-1}$
Force.	$m\,l\,t^{-2}$
Moment of a couple, or torque.	$m\,l^2\,t^{-2}$
Intensity of stress.	$m\,l^{-1}\,t^{-2}$
Modulus of elasticity.	$m\,l^{-1}\,t^{-2}$
Work and energy.	$m\,l^2\,t^{-2}$
Resilience.	$m\,l^{-1}\,t^{-2}$
Power or activity.	$m\,l^2\,t^{-3}$

TABLE 1.

FUNDAMENTAL AND DERIVED UNITS.

II. Heat Units.

Name of Unit.	Conversion Factor.
Quantity of heat (thermal units).	$m\,\theta$
" " (thermometric units).	$l^2\,\theta$
" " (dynamical units).	$m\,l^2\,t^{-2}$
Coefficient of thermal expansion.	θ^{-1}
Conductivity (thermal units).	$m\,l^{-1}\,t^{-1}$
" (thermometric units), or diffusivity.	$l^2\,t^{-1}$
" (dynamical units).	$m\,l\,t^{-3}\,\theta^{-1}$
Thermal capacity.	m
Latent heat (thermal units).	θ
" " (dynamical units).	$l^2\,t^{-2}$
Joule's equivalent.	$l^2\,t^{-2}\,\theta$
Entropy (heat measured in thermal units).	m
" (" " " dynamical units).	$m\,l^2\,t^{-2}\,\theta$

III. Magnetic and Electric Units.

Name of Unit.	Conversion factor for electrostatic system.	Conversion factor for electromagnetic system.
Magnetic pole, or quantity of magnetism.	$m^{\frac{1}{2}}\,l^{\frac{1}{2}}\,k^{-\frac{1}{2}}$	$m^{\frac{1}{2}}\,l^{\frac{3}{2}}\,t^{-1}\,p^{\frac{1}{2}}$
Density of surface distribution of magnetism.	$m^{\frac{1}{2}}\,l^{-\frac{1}{2}}\,k^{-\frac{1}{2}}$	$m^{\frac{1}{2}}\,l^{-\frac{1}{2}}\,t^{-1}\,p^{\frac{1}{2}}$
Intensity of magnetic field.	$m^{\frac{1}{2}}\,l^{\frac{1}{2}}\,t^{-2}\,k^{\frac{1}{2}}$	$m^{\frac{1}{2}}\,l^{-\frac{1}{2}}\,t^{-1}\,p^{-\frac{1}{2}}$
Magnetic potential.	$m^{\frac{1}{2}}\,l^{\frac{3}{2}}\,t^{-2}\,k^{\frac{1}{2}}$	$m^{\frac{1}{2}}\,l^{\frac{1}{2}}\,t^{-1}\,p^{-\frac{1}{2}}$
Magnetic moment.	$m^{\frac{1}{2}}\,l^{\frac{3}{2}}\,k^{-\frac{1}{2}}$	$m^{\frac{1}{2}}\,l^{\frac{5}{2}}\,t^{-1}\,p^{\frac{1}{2}}$
Intensity of magnetisation.	$m^{\frac{1}{2}}\,l^{\frac{1}{2}}\,k^{-\frac{1}{2}}$	$m^{\frac{1}{2}}\,l^{-\frac{1}{2}}\,t^{-1}\,p^{\frac{1}{2}}$
Magnetic permeability.	1	1
Magnetic susceptibility and magnetic inductive capacity.	$t^{-2}\,t^2\,k^{-1}$	p
Quantity of electricity.	$m^{\frac{1}{2}}\,l^{\frac{3}{2}}\,t^{-1}\,k^{\frac{1}{2}}$	$m^{\frac{1}{2}}\,l^{\frac{3}{2}}\,p^{-\frac{1}{2}}$
Electric surface density and electric displacement.	$m^{\frac{1}{2}}\,l^{-\frac{1}{2}}\,t^{-1}\,k^{\frac{1}{2}}$	$m^{\frac{1}{2}}\,l^{-\frac{1}{2}}\,p^{-\frac{1}{2}}$
Intensity of electric field.	$m^{\frac{1}{2}}\,l^{-\frac{1}{2}}\,t^{-1}\,k^{-\frac{1}{2}}$	$m^{\frac{1}{2}}\,l^{\frac{1}{2}}\,t^{-2}\,p^{\frac{1}{2}}$
Electric potential and e. m. f.	$m^{\frac{1}{2}}\,l^{\frac{1}{2}}\,t^{-1}\,k^{-\frac{1}{2}}$	$m^{\frac{1}{2}}\,l^{\frac{1}{2}}\,t^{-2}\,p^{\frac{1}{2}}$
Capacity of a condenser.	$l\,k$	$l^{-1}\,t^2\,p^{-1}$
Inductive capacity.	k	$l^{-2}\,t^2\,p^{-1}$
Specific inductive capacity.	1	1
Electric current.	$m^{\frac{1}{2}}\,l^{\frac{1}{2}}\,t^{-2}\,k^{\frac{1}{2}}$	$m^{\frac{1}{2}}\,l^{\frac{1}{2}}\,t^{-1}\,p^{-\frac{1}{2}}$

TABLE 1.

FUNDAMENTAL AND DERIVED UNITS.

III. Magnetic and Electric Units.

Name of Unit.	Conversion factor for electrostatic system.	Conversion factor for electromagnetic system.
Conductivity.	$t^{-1} k$	$l^{-2} t p^{-1}$
Specific resistance.	$t k^{-1}$	$l^2 t^{-1} p$
Conductance.	$l t^{-1} k$	$l^{-1} t p^{-1}$
Resistance.	$l^{-1} t k^{-1}$	$l t^{-1} p$
Coefficient of self induction and coefficient of mutual induction.	$l^{-1} t^2 k^{-1}$	$l p$
Electrokinetic momentum.	$m^{\frac{1}{2}} l^{\frac{1}{2}} k^{-\frac{1}{2}}$	$m^{\frac{1}{2}} l^{\frac{1}{2}} t^{-1} p^{\frac{1}{2}}$
Electromotive force at a point.	$m^{\frac{1}{2}} l^{-\frac{1}{2}} t^{-1} k^{-\frac{1}{2}}$	$m^{\frac{1}{2}} l^{\frac{1}{2}} t^{-2} p^{\frac{1}{2}}$
Vector potential.	$m^{\frac{1}{2}} l^{-\frac{1}{2}} k^{-\frac{1}{2}}$	$m^{\frac{1}{2}} l^{\frac{1}{2}} t^{-1} p^{\frac{1}{2}}$
Thermoelectric height and specific heat of electricity.	$m^{\frac{1}{2}} l^{\frac{1}{2}} t^{-1} k^{-\frac{1}{2}} \theta^{-1}$	$m^{\frac{1}{2}} l^{\frac{1}{2}} t^{-2} p^{\frac{1}{2}} \theta^{-1}$
Coefficient of Peltier effect.	$m^{\frac{1}{2}} l^{-\frac{1}{2}} t k^{-\frac{1}{2}} \theta$	$m^{\frac{1}{2}} l^{-\frac{1}{2}} p^{\frac{1}{2}} \theta$

TABLES FOR CONVERTING U. S. WEIGHTS AND MEASURES.*

(1) CUSTOMARY TO METRIC.

LINEAR.

	Inches to millimetres.	Feet to metres.	Yards to metres.	Miles to kilometres.
1	25.4001	0.304801	0.914402	1.60935
2	50.8001	0.609601	1.828804	3.21869
3	76.2002	0.914402	2.743205	4.82804
4	101.6002	1.219202	3.657607	6.43739
5	127.0003	1.524003	4.572009	8.04674
6	152.4003	1.828804	5.486411	9.65608
7	177.8004	2.133604	6.400813	11.26543
8	203.2004	2.438405	7.315215	12.87478
9	228.6005	2.743205	8.229616	14.48412

CAPACITY.

	Fluid drams to millilitres or cubic centimetres.	Fluid ounces to millilitres.	Liquid quarts to litres.	Gallons to litres.
1	3.70	29.57	0.94636	3.78543
2	7.39	59.15	1.89272	7.57087
3	11.09	88.72	2.83908	11.35630
4	14.79	118.29	3.78543	15.14174
5	18.48	147.87	4.73179	18.92717
6	22.18	177.44	5.67815	22.71261
7	25.88	207.02	6.62451	26.49804
8	29.57	236.59	7.57087	30.28348
9	33.27	266.16	8.51723	34.06891

SQUARE.

	Square inches to square centimetres.	Square feet to square decimetres.	Square yards to square metres.	Acres to hectares.
1	6.452	9.290	0.836	0.4047
2	12.903	18.581	1.672	0.8094
3	19.355	27.871	2.508	1.2141
4	25.807	37.161	3.345	1.6187
5	32.258	46.452	4.181	2.0234
6	38.710	55.742	5.017	2.4281
7	45.161	65.032	5.853	2.8328
8	51.613	74.323	6.689	3.2375
9	58.065	83.613	7.525	3.6422

WEIGHT.

	Grains to milligrammes.	Avoirdupois ounces to grammes.	Avoirdupois pounds to kilogrammes.	Troy ounces to grammes.
1	64.7989	28.3495	0.45359	31.10348
2	129.5978	56.6991	0.90718	62.20696
3	194.3968	85.0486	1.36078	93.31044
4	259.1957	113.3981	1.81437	124.41392
5	323.9946	141.7476	2.26796	155.51740
6	388.7935	170.0972	2.72155	186.62088
7	453.5924	198.4467	3.17515	217.72437
8	518.3913	226.7962	3.62874	248.82785
9	583.1903	255.1457	4.08233	279.93133

CUBIC.

	Cubic inches to cubic centimetres.	Cubic feet to cubic metres.	Cubic yards to cubic metres.	Bushels to hectolitres.
1	16.387	0.02832	0.765	0.35239
2	32.774	0.05663	1.529	0.70479
3	49.161	0.08495	2.294	1.05718
4	65.549	0.11327	3.058	1.40957
5	81.936	0.14159	3.823	1.76196
6	98.323	0.16990	4.587	2.11436
7	114.710	0.19822	5.352	2.46675
8	131.097	0.22654	6.116	2.81914
9	147.484	0.25485	6.881	3.17154

1 Gunter's chain	=	20.1168	metres.
1 sq. statute mile	=	259.000	hectares.
1 fathom	=	1.829	metres.
1 nautical mile	=	1853.25	metres.
1 foot	=	0.304801	metre.
1 avoir. pound	=	453.5924277	grammes.
15432.35639 grains	=	1.000	kilogramme.

According to an executive order dated April 15, 1893, the United States yard is defined as 3600/3937 metre, and the avoirdupois pound as 1/2.20462 kilogramme.

The only authorized material standard of customary weight is the Troy pound of the Mint. It is of brass of unknown density, and therefore not suitable for a standard of mass. It was derived from the British standard Troy pound of 1758 by direct comparison.

The British gallon = 4.545631 litres.

The British bushel = 36.3477 litres.

The length of the nautical mile given above and adopted by the U. S. Coast and Geodetic Survey many years ago, is defined as that of a minute of arc of a great circle of a sphere whose surface equals that of the earth (Clarke's Spheroid of 1866).

* Quoted from sheets issued by the United States Bureau of Standards.

TABLES FOR CONVERTING U. S. WEIGHTS AND MEASURES.

(2) METRIC TO CUSTOMARY.

LINEAR.

	Metres to inches.	Metres to feet.	Metres to yards.	Kilometres to miles.
1	39.3700	3.28083	1.093611	0.621357
2	78.7400	6.56167	2.187222	1.242714
3	118.1100	9.84250	3.280833	1.864071
4	157.4800	13.12333	4.374444	2.485428
5	196.8500	16.40417	5.468056	3.106785
6	236.2200	19.68500	6.561667	3.728142
7	275.5900	22.96583	7.655278	4.349499
8	314.9600	26.24667	8.748889	4.970856
9	354.3300	29.52750	9.842500	5.592213

CAPACITY.

	Millilitres or cubic centimetres to fluid drams.	Centilitres to fluid ounces.	Litres to quarts.	Decalitres to gallons.	Hectolitres to bushels.
1	0.27	0.338	1.0567	2.6417	2.8377
2	0.54	0.676	2.1134	5.2834	5.6755
3	0.81	1.014	3.1700	7.9251	8.5132
4	1.08	1.353	4.2267	10.5668	11.3510
5	1.35	1.691	5.2834	13.2085	14.1887
6	1.62	2.029	6.3401	15.8502	17.0265
7	1.89	2.367	7.3968	18.4919	19.8642
8	2.16	2.705	8.4535	21.1336	22.7019
9	2.43	3.043	9.5101	23.7753	25.5397

SQUARE.

	Square centimetres to square inches.	Square metres to square feet.	Square metres to square yards.	Hectares to acres.
1	0.1550	10.764	1.196	2.471
2	0.3100	21.528	2.392	4.942
3	0.4650	32.292	3.588	7.413
4	0.6200	43.055	4.784	9.884
5	0.7750	53.819	5.980	12.355
6	0.9300	64.583	7.176	14.826
7	1.0850	75.347	8.372	17.297
8	1.2400	86.111	9.568	19.768
9	1.3950	96.875	10.764	22.239

WEIGHT.

	Milligrammes to grains.	Kilogrammes to grains.	Hectogrammes to ounces avoirdupois.	Kilogrammes to pounds avoirdupois.
1	0.015432	15432.36	3.5274	2.20462
2	0.030864	30864.72	7.0548	4.40924
3	0.046296	46297.07	10.5822	6.61387
4	0.061728	61729.43	14.1096	8.81849
5	0.077160	77161.78	17.6370	11.02311
6	0.092592	92594.14	21.1644	13.22773
7	0.108024	108026.49	24.6918	15.43236
8	0.123456	123458.85	28.2192	17.63698
9	0.138889	138891.21	31.7466	19.84160

CUBIC.

	Cubic centimetres to cubic inches.	Cubic decimetres to cubic inches.	Cubic metres to cubic feet.	Cubic metres to cubic yards.
1	0.0610	61.023	35.314	1.308
2	0.1220	122.047	70.629	2.616
3	0.1831	183.070	105.943	3.924
4	0.2441	244.094	141.258	5.232
5	0.3051	305.117	176.572	6.540
6	0.3661	366.140	211.887	7.848
7	0.4272	427.164	247.201	9.156
8	0.4882	488.187	282.516	10.464
9	0.5492	549.210	317.830	11.771

WEIGHT.

	Quintals to pounds av.	Milliers or tonnes to pounds av.	Kilogrammes to ounces Troy.
1	220.46	2204.6	32.1507
2	440.92	4409.2	64.3015
3	661.39	6613.9	96.4522
4	881.85	8818.5	128.6030
5	1102.31	11023.1	160.7537
6	1322.77	13227.7	192.9045
7	1543.24	15432.4	225.0552
8	1763.70	17637.0	257.2059
9	1984.16	19841.6	289.3567

By the concurrent action of the principal governments of the world an International Bureau of Weights and Measures has been established near Paris. Under the direction of the International Committee, two ingots were cast of pure platinum-iridium in the proportion of 9 parts of the former to 1 of the latter metal. From one of these a certain number of kilogrammes were prepared, from the other a definite number of metre bars. These standards of weight and length were intercompared, without preference, and certain ones were selected as International prototype standards. The others were distributed by lot, in September, 1889, to the different governments, and are called National prototype standards. Those apportioned to the United States were received in 1890, and are kept at the Bureau of Standards in Washington, D. C.

The metric system was legalized in the United States in 1866.

The International Standard Metre is derived from the Mètre des Archives, and its length is defined by the distance between two lines at 0° Centigrade, on a platinum-iridium bar deposited at the International Bureau of Weights and Measures.

The International Standard Kilogramme is a mass of platinum-iridium deposited at the same place, and its weight is the same as that of the Kilogramme des Archives.

The litre is equal to a cubic decimetre, and it is measured by the quantity of distilled water which, at its maximum density, will counterpoise the standard kilogramme in a vacuum, the volume of such a quantity of water being, as has been ascertained, equal to a cubic decimetre.

EQUIVALENTS OF METRIC AND BRITISH IMPERIAL WEIGHTS AND MEASURES.*

(1) METRIC TO IMPERIAL.

LINEAR MEASURE.

1 millimetre (mm.) (.001 m.)	=	0.03937 in.
1 centimetre (.01 m.)	=	0.39370 "
1 decimetre (.1 m.)	=	3.93701 "
1 METRE (m.)	=	39.370113 " / 3.280843 ft. / 1.09361425 yds.
1 dekametre (10 m.)	=	10.93614 "
1 hectometre (100 m.)	=	109.361425 "
1 kilometre (1,000 m.)	=	0.62137 mile.
1 myriametre (10,000 m.)	=	6.21372 miles.
1 micron	=	0.001 mm.

SQUARE MEASURE.

1 sq. centimetre	=	0.1550 sq. in.
1 sq. decimetre (100 sq. centm.)	=	15.500 sq. in.
1 sq. metre or centiare (100 sq. dcm.)	=	10.7639 sq. ft. / 1.1960 sq. yds.
1 ARE (100 sq. m.)	=	119.60 sq. yds.
1 hectare (100 ares or 10,000 sq. m.)	=	2.4711 acres.

CUBIC MEASURE.

1 cub. centimetre (c.c.) (1,000 cubic millimetres)	=	0.0610 cub. in.
1 cub. decimetre (c.d.) (1,000 cubic centimetres)	=	61.024 " "
1 CUB. METRE or stere (1,000 c.d.)	=	35.3148 cub. ft. / 1.307954 cub. yds.

MEASURE OF CAPACITY.

1 millilitre (ml.) (.001 litre)	=	0.0610 cub. in.
1 centilitre (.01 litre)	=	0.61024 " " / 0.070 gill.
1 decilitre (.1 litre)	=	0.176 pint.
1 LITRE (1,000 cub. centimetres or 1 cub. decimetre)	=	1.75980 pints.
1 dekalitre (10 litres)	=	2.200 gallons.
1 hectolitre (100 ")	=	2.75 bushels.
1 kilolitre (1,000 ")	=	3.437 quarters.

APOTHECARIES' MEASURE.

1 cubic centimetre (1 gramme w't)	=	0.03520 fluid ounce. / 0.28157 fluid drachm. / 15.43236 grains weight.
1 cub. millimetre	=	0.01693 minim.

AVOIRDUPOIS WEIGHT.

1 milligramme (mgr.)	=	0.01543 grain.
1 centigramme (.01 gram.)	=	0.15432 "
1 decigramme (.1 ")	=	1.54324 grains.
1 GRAMME	=	15.43236 "
1 dekagramme (10 gram.)	=	5.64383 drams.
1 hectogramme (100 ")	=	3.52739 oz.
1 KILOGRAMME (1,000 ")	=	2.2046223 lbs. / 15432.3564 grains.
1 myriagramme (10 kilog.)	=	22.04622 lbs.
1 quintal (100 ")	=	1.96841 cwt.
1 millier or tonne (1,000 kilog.)	=	0.9842 ton.

TROY WEIGHT.

1 GRAMME	=	0.03215 oz. Troy. / 0.64301 pennyweight. / 15.43236 grains.

APOTHECARIES' WEIGHT.

1 GRAMME	=	0.25721 drachm. / 0.77162 scruple. / 15.43236 grains.

NOTE.—The METRE is the length, at the temperature of 0° C., of the platinum-iridium bar deposited at the International Bureau of Weights and Measures at Sevres, near Paris, France.

The present legal equivalent of the metre is 39.370113 inches, as above stated.

The KILOGRAMME is the mass of a platinum-iridium weight deposited at the same place.

The LITRE contains one kilogramme weight of distilled water at its maximum density (4° C.), the barometer being at 760 millimetres.

*In accordance with the schedule adopted under the Weights and Measures (metric system) Act, 1897.

TABLE 3.

EQUIVALENTS OF METRIC AND BRITISH IMPERIAL WEIGHTS AND MEASURES.

(2) METRIC TO IMPERIAL.

LINEAR MEASURE.

	Millimetres to inches.	Metres to feet.	Metres to yards.	Kilometres to miles.
1	0.03937011	3.28084	1.09361	0.62137
2	0.07874023	6.56169	2.18723	1.24274
3	0.11811034	9.84253	3.28084	1.86412
4	0.15748045	13.12337	4.37446	2.48549
5	0.19685056	16.40421	5.46807	3.10686
6	0.23622068	19.68506	6.56169	3.72823
7	0.27559079	22.96590	7.65530	4.34960
8	0.31496090	26.24674	8.74891	4.97097
9	0.35433102	29.52758	9.84253	5.59235

MEASURE OF CAPACITY.

	Litres to pints.	Dekalitres to gallons.	Hectolitres to bushels.	Kilolitres to quarters.
1	1.75980	2.19975	2.74969	3.43712
2	3.51961	4.39951	5.49938	6.87423
3	5.27941	6.59926	8.24908	10.31135
4	7.03921	8.79902	10.99877	13.74846
5	8.79902	10.99877	13.74846	17.18558
6	10.55882	13.19852	16.49815	20.62269
7	12.31862	15.39828	19.24785	24.05981
8	14.07842	17.59803	21.99754	27.49692
9	15.83823	19.79778	24.74723	30.93404

SQUARE MEASURE.

	Square centimetres to square inches.	Square metres to square feet.	Square metres to square yards.	Hectares to acres.
1	0.15500	10.76393	1.19599	2.4711
2	0.31000	21.52786	2.39198	4.9421
3	0.46500	32.29179	3.58798	7.4132
4	0.62000	43.05572	4.78397	9.8842
5	0.77500	53.81965	5.97996	12.3553
6	0.93000	64.58357	7.17595	14.8263
7	1.08500	75.34750	8.37194	17.2974
8	1.24000	86.11143	9.56794	19.7685
9	1.39501	96.87536	10.76393	22.2395

WEIGHT (AVOIRDUPOIS).

	Milligrammes to grains.	Kilogrammes to grains.	Kilogrammes to pounds.	Quintals to hundredweights.
1	0.01543	15432.356	2.20462	1.96841
2	0.03086	30864.713	4.40924	3.93683
3	0.04630	46297.069	6.61387	5.90524
4	0.06173	61729.426	8.81849	7.87365
5	0.07716	77161.782	11.02311	9.84206
6	0.09259	92594.138	13.22773	11.81048
7	0.10803	108026.495	15.43236	13.77889
8	0.12346	123458.851	17.63698	15.74730
9	0.13889	138891.208	19.84160	17.71572

CUBIC MEASURE.

	Cubic decimetres to cubic inches.	Cubic metres to cubic feet.	Cubic metres to cubic yards.	Apothecaries' Measure. Cub. centimetres to fluid drachms.
1	61.02390	35.31476	1.30795	0.28157
2	122.04781	70.62952	2.61591	0.56314
3	183.07171	105.94428	3.92386	0.84471
4	244.09561	141.25904	5.23182	1.12627
5	305.11952	176.57379	6.53977	1.40784
6	366.14342	211.88855	7.84772	1.68941
7	427.16732	247.20331	9.15568	1.97098
8	488.19123	282.51807	10.46363	2.25255
9	549.21513	317.83283	11.77159	2.53412

AVOIRDUPOIS (*cont.*) — TROY WEIGHT. — APOTHECARIES' WEIGHT.

	Milliers or tonnes to tons.	Grammes to ounces Troy.	Grammes to pennyweights.	Grammes to scruples.
1	0.98421	0.03215	0.64301	0.77162
2	1.96841	0.06430	1.28603	1.54324
3	2.95262	0.09645	1.92904	2.31485
4	3.93683	0.12860	2.57206	3.08647
5	4.92103	0.16075	3.21507	3.85809
6	5.90524	0.19290	3.85809	4.62971
7	6.88944	0.22506	4.50110	5.40132
8	7.87365	0.25721	5.14412	6.17294
9	8.85786	0.28936	5.78713	6.94456

TABLE 3.

EQUIVALENTS OF BRITISH IMPERIAL AND METRIC WEIGHTS AND MEASURES.

(3) IMPERIAL TO METRIC.

LINEAR MEASURE.

1 inch	=	25.400 millimetres.
1 foot (12 in.)	=	0.30480 metre.
1 YARD (3 ft.)	=	0.914399 "
1 pole (5½ yd.)	=	5.0292 metres.
1 chain (22 yd. or 100 links)	=	20.1168 "
1 furlong (220 yd.)	=	201.168 "
1 mile (1,760 yd.)	=	1.6093 kilometres.

SQUARE MEASURE.

1 square inch	=	6.4516 sq. centimetres.
1 sq. ft. (144 sq. in.)	=	9.2903 sq. decimetres.
1 SQ. YARD (9 sq. ft.)	=	0.836126 sq. metres.
1 perch (30¼ sq. yd.)	=	25.293 sq. metres.
1 rood (40 perches)	=	10.117 ares.
1 ACRE (4840 sq. yd.)	=	0.40468 hectare.
1 sq. mile (640 acres)	=	259.00 hectares.

CUBIC MEASURE.

1 cub. inch	=	16.387 cub. centimetres.
1 cub. foot (1728 cub. in.)	=	0.028317 cub. metre, or 28.317 cub. decimetres.
1 CUB. YARD (27 cub. ft.)	=	0.76455 cub. metre.

APOTHECARIES' MEASURE.

1 gallon (8 pints or 160 fluid ounces)	=	4.5459631 litres.
1 fluid ounce, f ʒ (8 drachms)	=	28.4123 cubic centimetres.
1 fluid drachm, f ʒ (60 minims)	=	3.5515 cubic centimetres.
1 minim, ♏ (0.91146 grain weight)	=	0.05919 cubic centimetres.

NOTE. — The Apothecaries' gallon is of the same capacity as the Imperial gallon.

MEASURE OF CAPACITY.

1 gill	=	1.42 decilitres.
1 pint (4 gills)	=	0.568 litre.
1 quart (2 pints)	=	1.136 litres.
1 GALLON (4 quarts)	=	4.5459631 "
1 peck (2 galls.)	=	9.092 "
1 bushel (8 galls.)	=	3.637 dekalitres.
1 quarter (8 bushels)	=	2.909 hectolitres.

AVOIRDUPOIS WEIGHT.

1 grain	=	64.8 milligrammes.
1 dram	=	1.772 grammes.
1 ounce (16 dr.)	=	28.350 "
1 POUND (16 oz. or 7,000 grains)	=	0.45359243 kilogr.
1 stone (14 lb.)	=	6.350 "
1 quarter (28 lb.)	=	12.70 "
1 hundredweight (112 lb.)	=	50.80 " / 0.5080 quintal.
1 ton (20 cwt.)	=	1.0160 tonnes or 1016 kilogrammes.

TROY WEIGHT.

1 Troy OUNCE (480 grains avoir.)	=	31.1035 grammes.
1 pennyweight (24 grains)	=	1.5552 "

NOTE. — The Troy grain is of the same weight as the Avoirdupois grain.

APOTHECARIES' WEIGHT.

1 ounce (8 drachms)	=	31.1035 grammes.
1 drachm, ℥ i (3 scruples)	=	3.888 "
1 scruple, ℈ i (20 grains)	=	1.296 "

NOTE. — The Apothecaries' ounce is of the same weight as the Troy ounce. The Apothecaries' grain is also of the same weight as the Avoirdupois grain.

NOTE. — The YARD is the length at 62° Fahr., marked on a bronze bar deposited with the Board of Trade.
The POUND is the weight of a piece of platinum weighed in vacuo at the temperature of 0° C., and which is also deposited with the Board of Trade.
The GALLON contains 10 lb. weight of distilled water at the temperature of 62° Fahr., the barometer being at 30 inches.

TABLE 3.

EQUIVALENTS OF BRITISH IMPERIAL AND METRIC WEIGHTS AND MEASURES.

(4) IMPERIAL TO METRIC.

LINEAR MEASURE.

	Inches to centimetres.	Feet to metres.	Yards to metres.	Miles to kilo-metres.
1	2.539998	0.30480	0.91440	1.60934
2	5.079996	0.60960	1.82880	3.21869
3	7.619993	0.91440	2.74320	4.82803
4	10.159991	1.21920	3.65760	6.43737
5	12.699989	1.52400	4.57200	8.04671
6	15.239987	1.82880	5.48640	9.65606
7	17.779984	2.13360	6.40080	11.26540
8	20.319982	2.43840	7.31519	12.87474
9	22.859980	2.74320	8.22959	14.48408

MEASURE OF CAPACITY.

	Quarts to litres.	Gallons to litres.	Bushels to dekalitres.	Quarters to hectolitres.
1	1.13649	4.54596	3.63677	2.90942
2	2.27298	9.09193	7.27354	5.81883
3	3.40947	13.63789	10.91031	8.72825
4	4.54596	18.18385	14.54708	11.63767
5	5.68245	22.72982	18.18385	14.54708
6	6.81894	27.27578	21.82062	17.45650
7	7.95544	31.82174	25.45739	20.36591
8	9.09193	36.36770	29.09416	23.27533
9	10.22842	40.91367	32.73093	26.18475

SQUARE MEASURE.

	Square inches to square centimetres.	Square feet to square decimetres.	Square yards to square metres.	Acres to hectares.
1	6.45159	9.29029	0.83613	0.40468
2	12.90318	18.58058	1.67225	0.80937
3	19.35477	27.87086	2.50838	1.21405
4	25.80636	37.16115	3.34450	1.61874
5	32.25794	46.45144	4.18063	2.02342
6	38.70953	55.74173	5.01676	2.42811
7	45.16112	65.03201	5.85288	2.83279
8	51.61271	74.32230	6.68901	3.23748
9	58.06430	83.61259	7.52513	3.64216

WEIGHT (AVOIRDUPOIS).

	Grains to milli-grammes.	Ounces to grammes.	Pounds to kilo-grammes.	Hundred-weights to quintals.
1	64.79892	28.34953	0.45359	0.50802
2	129.59784	56.69905	0.90718	1.01605
3	194.39675	85.04858	1.36078	1.52407
4	259.19567	113.39811	1.81437	2.03209
5	323.99459	141.74763	2.26796	2.54012
6	388.79351	170.09716	2.72155	3.04814
7	453.59243	198.44669	3.17515	3.55616
8	518.39135	226.79621	3.62874	4.06419
9	583.19026	255.14574	4.08233	4.57221

CUBIC MEASURE.

	Cubic inches to cubic centimetres.	Cubic feet to cubic metres.	Cubic yards to cubic metres	APOTHECARIES' MEASURE. Fluid drachms to cubic centi-metres.
1	16.38702	0.02832	0.76455	3.55153
2	32.77404	0.05663	1.52911	7.10307
3	49.16106	0.08495	2.29366	10.65460
4	65.54808	0.11327	3.05821	14.20613
5	81.93511	0.14158	3.82276	17.75767
6	98.32213	0.16990	4.58732	21.30920
7	114.70915	0.19822	5.35187	24.86074
8	131.09617	0.22653	6.11642	28.41227
9	147.48319	0.25485	6.88098	31.96380

AVOIRDUPOIS (*cont.*). TROY WEIGHT. APOTHECARIES' WEIGHT.

	Tons to milliers or tonnes.	Ounces to grammes.	Penny-weights to grammes.	Scruples to grammes.
1	1.01605	31.10348	1.55517	1.29598
2	2.03209	62.20696	3.11035	2.59196
3	3.04814	93.31044	4.66552	3.88794
4	4.06419	124.41392	6.22070	5.18391
5	5.08024	155.51740	7.77587	6.47989
6	6.09628	186.62088	9.33104	7.77587
7	7.11233	217.72437	10.88622	9.07185
8	8.12838	248.82785	12.44139	10.36783
9	9.14442	279.93133	13.99657	11.66381

VOLUME OF A GLASS VESSEL FROM THE WEIGHT OF ITS EQUIVALENT VOLUME OF MERCURY OR WATER.

If a glass vessel contains at $t°$ C, P grammes of mercury, weighted with brass weights in air at 760 mm. pressure, then its volume in c. cm.

at the same temperature, t, : $V = PR = P\frac{p}{d}$,

at another temperature, t_1, : $V = PR_1 = P\,p/d\,[1 + \gamma\,(t_1 - t)]$

p = the weight, reduced to vacuum, of the mass of mercury or water which, weighed with brass weights, equals 1 gramme;

d = the density of mercury or water at $t°$ C,

and $\gamma = 0.000\,025$, is the cubical expansion coefficient of glass.

Temperature t	WATER.			MERCURY.		
	R.	R_1, $t_1 = 10°$.	R_1, $t_1 = 20°$.	R.	R_1, $t_1 = 10°$.	R_1, $t_1 = 20°$.
0°	1.001192	1.001443	1.001693	0.0735499	0.0735683	0.0735867
1	1133	1358	1609	5633	5798	5982
2	1092	1292	1542	5766	5914	6098
3	1068	1243	1493	5900	6029	6213
4	1060	1210	1460	6033	6144	6328
5	1068	1193	1443	6167	6259	6443
6	1.001092	1.001192	1.001442	0.0736301	0.0736374	0.0736558
7	1131	1206	1456	6434	6490	6674
8	1184	1234	1485	6568	6605	6789
9	1252	1277	1527	6702	6720	6904
10	1333	1333	1584	6835	6835	7020
11	1.001428	1.001403	001653	0.0736969	0.0736951	0.0737135
12	1536	1486	1736	7103	7066	7250
13	1657	1582	1832	7236	7181	7365
14	1790	1690	1940	7370	7297	7481
15	1935	1810	2060	7504	7412	7596
16	1.002092	1.001942	1.002193	0.0737637	0.0737527	0.0737711
17	2261	2086	2337	7771	7642	7826
18	2441	2241	2491	7905	7757	7941
19	2633	2407	2658	8039	7872	8057
20	2835	2584	2835	8172	7988	8172
21	1.003048	1.002772	1.003023	0.0738306	0.0738103	0.0738288
22	3271	2970	3220	8440	8218	8403
23	3504	3178	3429	8573	8333	8518
24	3748	3396	3647	8707	8449	8633
25	4001	3624	3875	8841	8564	8748
26	1.004264	1.003862	1.004113	0.0738974	0.0738679	0.0738864
27	4537	4110	4361	9108	8794	8979
28	4818	4366	4616	9242	8910	9094
29	5110	4632	4884	9376	9025	9210
30	5410	4908	5159	9510	9140	9325

Taken from Landolt, Börnstein, and Meyerhoffer's Physikalisch-Chemische Tabellen.

DIFFERENTIAL COEFFICIENTS.

INTEGRALS.

DIFFERENTIAL COEFFICIENTS.		INTEGRALS.	
$u=x^n$	$\frac{du}{dx}=nx^{n-1}$	$\int x^n dx$	$=\frac{x^{n+1}}{n+1}$
a^x	$a^x \log_e a$	$\int a^x dx$	$\frac{a^x}{\log_e a}$
e^x	e^x	$\int e^x dx$	e^x
$\log_e x$	$\frac{1}{x}$	$\int \frac{dx}{x}$	$\log_e x$
sin. x	cos. x	$\int \cos. ax \cdot dx$	$\frac{\sin. ax}{a}$
cos. x	$-\sin. x$	$\int \sin. ax \cdot dx$	$\frac{-\cos. ax}{a}$
tan. x	$\sec.^2 x$	$\int \sec.^2 ax \cdot dx$	$\frac{\tan. ax}{a}$
cot. x	$-\operatorname{cosec}.^2 x$	$\int \operatorname{cosec}.^2 ax \cdot dx$	$\frac{-\cot. ax}{a}$
sec. x	$\frac{\sin. x}{\cos.^2 x}$	$\int \frac{\sin. x}{\cos.^2 x} dx$	sec. x
cosec. x	$-\frac{\cos. x}{\sin.^2 x}$	$\int \frac{\cos. x}{\sin.^2 x} dx$	$-\operatorname{cosec}. x$
$\sin.^{-1} x$	$\frac{1}{\sqrt{(1-x^2)}}$	$\int \frac{dx}{\sqrt{(a^2-x^2)}}$	$\begin{cases} \sin.^{-1}\frac{x}{a} \\ -\cos.^{-1}\frac{x}{a} \end{cases}$
$\cos.^{-1} x$	$-\frac{1}{\sqrt{(1-x^2)}}$		
$\tan.^{-1} x$	$\frac{1}{1+x^2}$	$\int \frac{dx}{a^2+x^2}$	$\begin{cases} \frac{1}{a}\tan.^{-1}\frac{x}{a} \\ -\frac{1}{a}\cot.^{-1}\frac{x}{a} \end{cases}$
$\cot.^{-1} x$	$-\frac{1}{1+x^2}$		
$\sec.^{-1} x$	$\frac{1}{x\sqrt{(x^2-1)}}$	$\int \frac{dx}{x\sqrt{(x^2-a^2)}}$	$\begin{cases} \frac{1}{a}\sec.^{-1}\frac{x}{a} \\ -\frac{1}{a}\operatorname{cosec}.^{-1}\frac{x}{a} \end{cases}$
$\operatorname{cosec}.^{-1} x$	$-\frac{1}{x\sqrt{(x^2-1)}}$		
$\operatorname{vers}.^{-1} x$	$\frac{1}{\sqrt{(2x-x^2)}}$	$\int \frac{dx}{\sqrt{(2x-x^2)}}$	$\begin{cases} \operatorname{vers}.^{-1} x \\ -\operatorname{covers}.^{-1} x \end{cases}$
$\operatorname{covers}.^{-1} x$	$\frac{1}{\sqrt{(2x-x^2)}}$		

Taylor's series:

$$u=f(x+h)=f(x)+f'(x)h+f''(x)\frac{h^2}{2}+f'''(x)\frac{h^3}{1\cdot 2\cdot 3}+\cdots\cdots$$

The remainder after the first n terms is expressed by

$$\frac{1}{1\cdot 2\cdot 3\cdots n}\int_0^n f^{n+1}(x+h-z)z^n \cdot dz.$$

Maclaurin's series:

$$u=f(x)=f(0)+f'(0)x+f''(0)\frac{x^2}{1\cdot 2}+f'''(0)\frac{x^3}{1\cdot 2\cdot 3}+\cdots$$

$\pi=3.14159265359$
$\frac{1}{\pi}=0.31830988618$
$\pi^2=9.86960440109$
$e=2.71828182846$
$\sqrt{\pi}=1.77245385091$
$\frac{\sqrt{\pi}}{2}=0.88622692546$

$\log_{10}\pi=0.49714987269$
$\log_{10} e=0.43429448190$
$\log_e 10=2.30258509299$
$\log_B(\text{number})=\log_e(\text{number})\cdot\log_B e$
$=\frac{\log_e(\text{number})}{\log_e B}$

VALUES OF RECIPROCALS, SQUARES, CUBES, SQUARE ROOTS, OF NATURAL NUMBERS.

n	$1000.\frac{1}{n}$	n^2	n^3	$\sqrt{n}$	n	$1000.\frac{1}{n}$	n^2	n^3	$\sqrt{n}$
10	100.000	100	1000	3.1623	**65**	15.3846	4225	274625	8.0623
11	90.9091	121	1331	3.3166	66	15.1515	4356	287496	8.1240
12	83.3333	144	1728	3.4641	67	14.9254	4489	300763	8.1854
13	76.9231	169	2197	3.6056	68	14.7059	4624	314432	8.2462
14	71.4286	196	2744	3.7417	69	14.4928	4761	328509	8.3066
15	66.6667	225	3375	3.8730	**70**	14.2857	4900	343000	8.3666
16	62.5000	256	4096	4.0000	71	14.0845	5041	357911	8.4261
17	58.8235	289	4913	4.1231	72	13.8889	5184	373248	8.4853
18	55.5556	324	5832	4.2426	73	13.6986	5329	389017	8.5440
19	52.6316	361	6859	4.3589	74	13.5135	5476	405224	8.6023
20	50.0000	400	8000	4.4721	**75**	13.3333	5625	421875	8.6603
21	47.6190	441	9261	4.5826	76	13.1579	5776	438976	8.7178
22	45.4545	484	10648	4.6904	77	12.9870	5929	456533	8.7750
23	43.4783	529	12167	4.7958	78	12.8205	6084	474552	8.8318
24	41.6667	576	13824	4.8990	79	12.6582	6241	493039	8.8882
25	40.0000	625	15625	5.0000	**80**	12.5000	6400	512000	8.9443
26	38.4615	676	17576	5.0990	81	12.3457	6561	531441	9.0000
27	37.0370	729	19683	5.1962	82	12.1951	6724	551368	9.0554
28	35.7143	784	21952	5.2915	83	12.0482	6889	571787	9.1104
29	34.4828	841	24389	5.3852	84	11.9048	7056	592704	9.1652
30	33.3333	900	27000	5.4772	**85**	11.7647	7225	614125	9.2195
31	32.2581	961	29791	5.5678	86	11.6279	7396	636056	9.2736
32	31.2500	1024	32768	5.6569	87	11.4943	7569	658503	9.3274
33	30.3030	1089	35937	5.7446	88	11.3636	7744	681472	9.3808
34	29.4118	1156	39304	5.8310	89	11.2360	7921	704969	9.4340
35	28.5714	1225	42875	5.9161	**90**	11.1111	8100	729000	9.4868
36	27.7778	1296	46656	6.0000	91	10.9890	8281	753571	9.5394
37	27.0270	1369	50653	6.0828	92	10.8696	8464	778688	9.5917
38	26.3158	1444	54872	6.1644	93	10.7527	8649	804357	9.6437
39	25.6410	1521	59319	6.2450	94	10.6383	8836	830584	9.6954
40	25.0000	1600	64000	6.3246	**95**	10.5263	9025	857375	9.7468
41	24.3902	1681	68921	6.4031	96	10.4167	9216	884736	9.7980
42	23.8095	1764	74088	6.4807	97	10.3093	9409	912673	9.8489
43	23.2558	1849	79507	6.5574	98	10.2041	9604	941192	9.8995
44	22.7273	1936	85184	6.6332	99	10.1010	9801	970299	9.9499
45	22.2222	2025	91125	6.7082	**100**	10.0000	10000	1000000	10.0000
46	21.7391	2116	97336	6.7823	101	9.90099	10201	1030301	10.0499
47	21.2766	2209	103823	6.8557	102	9.80392	10404	1061208	10.0995
48	20.8333	2304	110592	6.9282	103	9.70874	10609	1092727	10.1489
49	20.4082	2401	117649	7.0000	104	9.61538	10816	1124864	10.1980
50	20.0000	2500	125000	7.0711	**105**	9.52381	11025	1157625	10.2470
51	19.6078	2601	132651	7.1414	106	9.43396	11236	1191016	10.2956
52	19.2308	2704	140608	7.2111	107	9.34579	11449	1225043	10.3441
53	18.8679	2809	148877	7.2801	108	9.25926	11664	1259712	10.3923
54	18.5185	2916	157464	7.3485	109	9.17431	11881	1295029	10.4403
55	18.1818	3025	166375	7.4162	**110**	9.09091	12100	1331000	10.4881
56	17.8571	3136	175616	7.4833	111	9.00901	12321	1367631	10.5357
57	17.5439	3249	185193	7.5498	112	8.92857	12544	1404928	10.5830
58	17.2414	3364	195112	7.6158	113	8.84956	12769	1442897	10.6301
59	16.9492	3481	205379	7.6811	114	8.77193	12996	1481544	10.6771
60	16.6667	3600	216000	7.7460	**115**	8.69565	13225	1520875	10.7238
61	16.3934	3721	226981	7.8102	116	8.62069	13456	1560896	10.7703
62	16.1290	3844	238328	7.8740	117	8.54701	13689	1601613	10.8167
63	15.8730	3969	250047	7.9373	118	8.47458	13924	1643032	10.8628
64	15.6250	4096	262144	8.0000	119	8.40336	14161	1685159	10.9087

VALUES OF RECIPROCALS, SQUARES, CUBES, SQUARE ROOTS, OF NATURAL NUMBERS.

n	$1000.\frac{1}{n}$	n^2	n^3	$\sqrt{n}$	n	$1000.\frac{1}{n}$	n^2	n^3	$\sqrt{n}$
120	8.33333	14400	1728000	10.9545	**175**	5.71429	30625	5359375	13.2288
121	8.26446	14641	1771561	11.0000	176	5.68182	30976	5451776	13.2665
122	8.19672	14884	1815848	11.0454	177	5.64972	31329	5545233	13.3041
123	8.13008	15129	1860867	11.0905	178	5.61798	31684	5639752	13.3417
124	8.06452	15376	1906624	11.1355	179	5.58659	32041	5735339	13.3791
125	8.00000	15625	1953125	11.1803	**180**	5.55556	32400	5832000	13.4164
126	7.93651	15876	2000376	11.2250	181	5.52486	32761	5929741	13.4536
127	7.87402	16129	2048383	11.2694	182	5.49451	33124	6028568	13.4907
128	7.81250	16384	2097152	11.3137	183	5.46448	33489	6128487	13.5277
129	7.75194	16641	2146689	11.3578	184	5.43478	33856	6229504	13.5647
130	7.69231	16900	2197000	11.4018	**185**	5.40541	34225	6331625	13.6015
131	7.63359	17161	2248091	11.4455	186	5.37634	34596	6434856	13.6382
132	7.57576	17424	2299968	11.4891	187	5.34759	34969	6539203	13.6748
133	7.51880	17689	2352637	11.5326	188	5.31915	35344	6644672	13.7113
134	7.46269	17956	2406104	11.5758	189	5.29101	35721	6751269	13.7477
135	7.40741	18225	2460375	11.6190	**190**	5.26316	36100	6859000	13.7840
136	7.35294	18496	2515456	11.6619	191	5.23560	36481	6967871	13.8203
137	7.29927	18769	2571353	11.7047	192	5.20833	36864	7077888	13.8564
138	7.24638	19044	2628072	11.7473	193	5.18135	37249	7189057	13.8924
139	7.19424	19321	2685619	11.7898	194	5.15464	37636	7301384	13.9284
140	7.14286	19600	2744000	11.8322	**195**	5.12821	38025	7414875	13.9642
141	7.09220	19881	2803221	11.8743	196	5.10204	38416	7529536	14.0000
142	7.04225	20164	2863288	11.9164	197	5.07614	38809	7645373	14.0357
143	6.99301	20449	2924207	11.9583	198	5.05051	39204	7762392	14.0712
144	6.94444	20736	2985984	12.0000	199	5.02513	39601	7880599	14.1067
145	6.89655	21025	3048625	12.0416	**200**	5.00000	40000	8000000	14.1421
146	6.84932	21316	3112136	12.0830	201	4.97512	40401	8120601	14.1774
147	6.80272	21609	3176523	12.1244	202	4.95050	40804	8242408	14.2127
148	6.75676	21904	3241792	12.1655	203	4.92611	41209	8365427	14.2478
149	6.71141	22201	3307949	12.2066	204	4.90196	41616	8489664	14.2829
150	6.66667	22500	3375000	12.2474	**205**	4.87805	42025	8615125	14.3178
151	6.62252	22801	3442951	12.2882	206	4.85437	42436	8741816	14.3527
152	6.57895	23104	3511808	12.3288	207	4.83092	42849	8869743	14.3875
153	6.53595	23409	3581577	12.3693	208	4.80769	43264	8998912	14.4222
154	6.49351	23716	3652264	12.4097	209	4.78469	43681	9129329	14.4568
155	6.45161	24025	3723875	12.4499	**210**	4.76190	44100	9261000	14.4914
156	6.41026	24336	3796416	12.4900	211	4.73934	44521	9393931	14.5258
157	6.36943	24649	3869893	12.5300	212	4.71698	44944	9528128	14.5602
158	6.32911	24964	3944312	12.5698	213	4.69484	45369	9663597	14.5945
159	6.28931	25281	4019679	12.6095	214	4.67290	45796	9800344	14.6287
160	6.25000	25600	4096000	12.6491	**215**	4.65116	46225	9938375	14.6629
161	6.21118	25921	4173281	12.6886	216	4.62963	46656	10077696	14.6969
162	6.17284	26244	4251528	12.7279	217	4.60829	47089	10218313	14.7309
163	6.13497	26569	4330747	12.7671	218	4.58716	47524	10360232	14.7648
164	6.09756	26896	4410944	12.8062	219	4.56621	47961	10503459	14.7986
165	6.06061	27225	4492125	12.8452	**220**	4.54545	48400	10648000	14.8324
166	6.02410	27556	4574296	12.8841	221	4.52489	48841	10793861	14.8661
167	5.98802	27889	4657463	12.9228	222	4.50450	49284	10941048	14.8997
168	5.95238	28224	4741632	12.9615	223	4.48431	49729	11089567	14.9332
169	5.91716	28561	4826809	13.0000	224	4.46429	50176	11239424	14.9666
170	5.88235	28900	4913000	13.0384	**225**	4.44444	50625	11390625	15.0000
171	5.84795	29241	5000211	13.0767	226	4.42478	51076	11543176	15.0333
172	5.81395	29584	5088448	13.1149	227	4.40529	51529	11697083	15.0665
173	5.78035	29929	5177717	13.1529	228	4.38596	51984	11852352	15.0997
174	5.74713	30276	5268024	13.1909	229	4.36681	52441	12008989	15.1327

VALUES OF RECIPROCALS, SQUARES, CUBES, AND SQUARE ROOTS, OF NATURAL NUMBERS.

n	$1000.\frac{1}{n}$	n^2	n^3	$\sqrt{n}$	n	$1000.\frac{1}{n}$	n^2	n^3	$\sqrt{n}$
230	4.34783	52900	12167000	15.1658	**285**	3.50877	81225	23149125	16.8819
231	4.32900	53361	12326391	15.1987	286	3.49650	81796	23393656	16.9115
232	4.31034	53824	12487168	15.2315	287	3.48432	82369	23639903	16.9411
233	4.29185	54289	12649337	15.2643	288	3.47222	82944	23887872	16.9706
234	4.27350	54756	12812904	15.2971	289	3.46021	83521	24137569	17.0000
235	4.25532	55225	12977875	15.3297	**290**	3.44828	84100	24389000	17.0294
236	4.23729	55696	13144256	15.3623	291	3.43643	84681	24642171	17.0587
237	4.21941	56169	13312053	15.3948	292	3.42466	85264	24897088	17.0880
238	4.20168	56644	13481272	15.4272	293	3.41297	85849	25153757	17.1172
239	4.18410	57121	13651919	15.4596	294	3.40136	86436	25412184	17.1464
240	4.16667	57600	13824000	15.4919	**295**	3.38983	87025	25672375	17.1756
241	4.14938	58081	13997521	15.5242	296	3.37838	87616	25934336	17.2047
242	4.13223	58564	14172488	15.5563	297	3.36700	88209	26198073	17.2337
243	4.11523	59049	14348907	15.5885	298	3.35570	88804	26463592	17.2627
244	4.09836	59536	14526784	15.6205	299	3.34448	89401	26730899	17.2916
245	4.08163	60025	14706125	15.6525	**300**	3.33333	90000	27000000	17.3205
246	4.06504	60516	14886936	15.6844	301	3.32226	90601	27270901	17.3494
247	4.04858	61009	15069223	15.7162	302	3.31126	91204	27543608	17.3781
248	4.03226	61504	15252992	15.7480	303	3.30033	91809	27818127	17.4069
249	4.01606	62001	15438249	15.7797	304	3.28947	92416	28094464	17.4356
250	4.00000	62500	15625000	15.8114	**305**	3.27869	93025	28372625	17.4642
251	3.98406	63001	15813251	15.8430	306	3.26797	93636	28652616	17.4929
252	3.96825	63504	16003008	15.8745	307	3.25733	94249	28934443	17.5214
253	3.95257	64009	16194277	15.9060	308	3.24675	94864	29218112	17.5499
254	3.93701	64516	16387064	15.9374	309	3.23625	95481	29503629	17.5784
255	3.92157	65025	16581375	15.9687	**310**	3.22581	96100	29791000	17.6068
256	3.90625	65536	16777216	16.0000	311	3.21543	96721	30080231	17.6352
257	3.89105	66049	16974593	16.0312	312	3.20513	97344	30371328	17.6635
258	3.87597	66564	17173512	16.0624	313	3.19489	97969	30664297	17.6918
259	3.86100	67081	17373979	16.0935	314	3.18471	98596	30959144	17.7200
260	3.84615	67600	17576000	16.1245	**315**	3.17460	99225	31255875	17.7482
261	3.83142	68121	17779581	16.1555	316	3.16456	99856	31554496	17.7764
262	3.81679	68644	17984728	16.1864	317	3.15457	100489	31855013	17.8045
263	3.80228	69169	18191447	16.2173	318	3.14465	101124	32157432	17.8326
264	3.78788	69696	18399744	16.2481	319	3.13480	101761	32461759	17.8606
265	3.77358	70225	18609625	16.2788	**320**	3.12500	102400	32768000	17.8885
266	3.75940	70756	18821096	16.3095	321	3.11527	103041	33076161	17.9165
267	3.74532	71289	19034163	16.3401	322	3.10559	103684	33386248	17.9444
268	3.73134	71824	19248832	16.3707	323	3.09598	104329	33698267	17.9722
269	3.71747	72361	19465109	16.4012	324	3.08642	104976	34012224	18.0000
270	3.70370	72900	19683000	16.4317	**325**	3.07692	105625	34328125	18.0278
271	3.69004	73441	19902511	16.4621	326	3.06748	106276	34645976	18.0555
272	3.67647	73984	20123648	16.4924	327	3.05810	106929	34965783	18.0831
273	3.66300	74529	20346417	16.5227	328	3.04878	107584	35287552	18.1108
274	3.64964	75076	20570824	16.5529	329	3.03951	108241	35611289	18.1384
275	3.63636	75625	20796875	16.5831	**330**	3.03030	108900	35937000	18.1659
276	3.62319	76176	21024576	16.6132	331	3.02115	109561	36264691	18.1934
277	3.61011	76729	21253933	16.6433	332	3.01205	110224	36594368	18.2209
278	3.59712	77284	21484952	16.6733	333	3.00300	110889	36926037	18.2483
279	3.58423	77841	21717639	16.7033	334	2.99401	111556	37259704	18.2757
280	3.57143	78400	21952000	16.7332	**335**	2.98507	112225	37595375	18.3030
281	3.55872	78961	22188041	16.7631	336	2.97619	112896	37933056	18.3303
282	3.54610	79524	22425768	16.7929	337	2.96736	113569	38272753	18.3576
283	3.53357	80089	22665187	16.8226	338	2.95858	114244	38614472	18.3848
284	3.52113	80656	22906304	16.8523	339	2.94985	114921	38958219	18.4120

VALUES OF RECIPROCALS, SQUARES, CUBES, AND SQUARE ROOTS OF NATURAL NUMBERS.

n	$1000\frac{1}{n}$	n^2	n^3	$\sqrt{n}$	n	$1000\frac{1}{n}$	n^2	n^3	$\sqrt{n}$
340	2.94118	115600	39304000	18.4391	**395**	2.53165	156025	61629875	19.8746
341	2.93255	116281	39651821	18.4662	396	2.52525	156816	62099136	19.8997
342	2.92398	116964	40001688	18.4932	397	2.51889	157609	62570773	19.9249
343	2.91545	117649	40353607	18.5203	398	2.51256	158404	63044792	19.9499
344	2.90698	118336	40707584	18.5472	399	2.50627	159201	63521199	19.9750
345	2.89855	119025	41063625	18.5742	**400**	2.50000	160000	64000000	20.0000
346	2.89017	119716	41421736	18.6011	401	2.49377	160801	64481201	20.0250
347	2.88184	120409	41781923	18.6279	402	2.48756	161604	64964808	20.0499
348	2.87356	121104	42144192	18.6548	403	2.48139	162409	65450827	20.0749
349	2.86533	121801	42508549	18.6815	404	2.47525	163216	65939264	20.0998
350	2.85714	122500	42875000	18.7083	**405**	2.46914	164025	66430125	20.1246
351	2.84900	123201	43243551	18.7350	406	2.46305	164836	66923416	20.1494
352	2.84091	123904	43614208	18.7617	407	2.45700	165649	67419143	20.1742
353	2.83286	124609	43986977	18.7883	408	2.45098	166464	67917312	20.1990
354	2.82486	125316	44361864	18.8149	409	2.44499	167281	68417929	20.2237
355	2.81690	126025	44738875	18.8414	**410**	2.43902	168100	68921000	20.2485
356	2.80899	126736	45118016	18.8680	411	2.43309	168921	69426531	20.2731
357	2.80112	127449	45499293	18.8944	412	2.42718	169744	69934528	20.2978
358	2.79330	128164	45882712	18.9209	413	2.42131	170569	70444997	20.3224
359	2.78552	128881	46268279	18.9473	414	2.41546	171396	70957944	20.3470
360	2.77778	129600	46656000	18.9737	**415**	2.40964	172225	71473375	20.3715
361	2.77008	130321	47045881	19.0000	416	2.40385	173056	71991296	20.3961
362	2.76243	131044	47437928	19.0263	417	2.39808	173889	72511713	20.4206
363	2.75482	131769	47832147	19.0526	418	2.39234	174724	73034632	20.4450
364	2.74725	132496	48228544	19.0788	419	2.38663	175561	73560059	20.4695
365	2.73973	133225	48627125	19.1050	**420**	2.38095	176400	74088000	20.4939
366	2.73224	133956	49027896	19.1311	421	2.37530	177241	74618461	20.5183
367	2.72480	134689	49430863	19.1572	422	2.36967	178084	75151448	20.5426
368	2.71739	135424	49836032	19.1833	423	2.36407	178929	75686967	20.5670
369	2.71003	136161	50243409	19.2094	424	2.35849	179776	76225024	20.5913
370	2.70270	136900	50653000	19.2354	**425**	2.35294	180625	76765625	20.6155
371	2.69542	137641	51064811	19.2614	426	2.34742	181476	77308776	20.6398
372	2.68817	138384	51478848	19.2873	427	2.34192	182329	77854483	20.6640
373	2.68097	139129	51895117	19.3132	428	2.33645	183184	78402752	20.6882
374	2.67380	139876	52313624	19.3391	429	2.33100	184041	78953589	20.7123
375	2.66667	140625	52734375	19.3649	**430**	2.32558	184900	79507000	20.7364
376	2.65957	141376	53157376	19.3907	431	2.32019	185761	80062991	20.7605
377	2.65252	142129	53582633	19.4165	432	2.31481	186624	80621568	20.7846
378	2.64550	142884	54010152	19.4422	433	2.30947	187489	81182737	20.8087
379	2.63852	143641	54439939	19.4679	434	2.30415	188356	81746504	20.8327
380	2.63158	144400	54872000	19.4936	**435**	2.29885	189225	82312875	20.8567
381	2.62467	145161	55306341	19.5192	436	2.29358	190096	82881856	20.8806
382	2.61780	145924	55742968	19.5448	437	2.28833	190969	83453453	20.9045
383	2.61097	146689	56181887	19.5704	438	2.28311	191844	84027672	20.9284
384	2.60417	147456	56623104	19.5959	439	2.27790	192721	84604519	20.9523
385	2.59740	148225	57066625	19.6214	**440**	2.27273	193600	85184000	20.9762
386	2.59067	148996	57512456	19.6469	441	2.26757	194481	85766121	21.0000
387	2.58398	149769	57960603	19.6723	442	2.26244	195364	86350888	21.0238
388	2.57732	150544	58411072	19.6977	443	2.25734	196249	86938307	21.0476
389	2.57069	151321	58863869	19.7231	444	2.25225	197136	87528384	21.0713
390	2.56410	152100	59319000	19.7484	**445**	2.24719	198025	88121125	21.0950
391	2.55754	152881	59776471	19.7737	446	2.24215	198916	88716536	21.1187
392	2.55102	153664	60236288	19.7990	447	2.23714	199809	89314623	21.1424
393	2.54453	154449	60698457	19.8242	448	2.23214	200704	89915392	21.1660
394	2.53807	155236	61162984	19.8494	449	2.22717	201601	90518849	21.1896

VALUES OF RECIPROCALS, SQUARES, CUBES, AND SQUARE ROOTS OF NATURAL NUMBERS.

n	$1000.\frac{1}{n}$	n^2	n^3	$\sqrt{n}$	n	$1000.\frac{1}{n}$	n^2	n^3	$\sqrt{n}$
450	2.22222	202500	91125000	21.2132	**505**	1.98020	255025	128787625	22.4722
451	2.21730	203401	91733851	21.2368	506	1.97628	256036	129554216	22.4944
452	2.21239	204304	92345408	21.2603	507	1.97239	257049	130323843	22.5167
453	2.20751	205209	92959677	21.2838	508	1.96850	258064	131096512	22.5389
454	2.20264	206116	93576664	21.3073	509	1.96464	259081	131872229	22.5610
455	2.19780	207025	94196375	21.3307	**510**	1.96078	260100	132651000	22.5832
456	2.19298	207936	94818816	21.3542	511	1.95695	261121	133432831	22.6053
457	2.18818	208849	95443993	21.3776	512	1.95312	262144	134217728	22.6274
458	2.18341	209764	96071912	21.4009	513	1.94932	263169	135005697	22.6495
459	2.17865	210681	96702579	21.4243	514	1.94553	264196	135796744	22.6716
460	2.17391	211600	97336000	21.4476	**515**	1.94175	265225	136590875	22.6936
461	2.16920	212521	97972181	21.4709	516	1.93798	266256	137388096	22.7156
462	2.16450	213444	98611128	21.4942	517	1.93424	267289	138188413	22.7376
463	2.15983	214369	99252847	21.5174	518	1.93050	268324	138991832	22.7596
464	2.15517	215296	99897344	21.5407	519	1.92678	269361	139798359	22.7816
465	2.15054	216225	100544625	21.5639	**520**	1.92308	270400	140608000	22.8035
466	2.14592	217156	101194696	21.5870	521	1.91939	271441	141420761	22.8254
467	2.14133	218089	101847563	21.6102	522	1.91571	272484	142236648	22.8473
468	2.13675	219024	102503232	21.6333	523	1.91205	273529	143055667	22.8692
469	2.13220	219961	103161709	21.6564	524	1.90840	274576	143877824	22.8910
470	2.12766	220900	103823000	21.6795	**525**	1.90476	275625	144703125	22.9129
471	2.12314	221841	104487111	21.7025	526	1.90114	276676	145531576	22.9347
472	2.11864	222784	105154048	21.7256	527	1.89753	277729	146363183	22.9565
473	2.11416	223729	105823817	21.7486	528	1.89394	278784	147197952	22.9783
474	2.10970	224676	106496424	21.7715	529	1.89036	279841	148035889	23.0000
475	2.10526	225625	107171875	21.7945	**530**	1.88679	280900	148877000	23.0217
476	2.10084	226576	107850176	21.8174	531	1.88324	281961	149721291	23.0434
477	2.09644	227529	108531333	21.8403	532	1.87970	283024	150568768	23.0651
478	2.09205	228484	109215352	21.8632	533	1.87617	284089	151419437	23.0868
479	2.08768	229441	109902239	21.8861	534	1.87266	285156	152273304	23.1084
480	2.08333	230400	110592000	21.9089	**535**	1.86916	286225	153130375	23.1301
481	2.07900	231361	111284641	21.9317	536	1.86567	287296	153990656	23.1517
482	2.07469	232324	111980168	21.9545	537	1.86220	288369	154854153	23.1733
483	2.07039	233289	112678587	21.9773	538	1.85874	289444	155720872	23.1948
484	2.06612	234256	113379904	22.0000	539	1.85529	290521	156590819	23.2164
485	2.06186	235225	114084125	22.0227	**540**	1.85185	291600	157464000	23.2379
486	2.05761	236196	114791256	22.0454	541	1.84843	292681	158340421	23.2594
487	2.05339	237169	115501303	22.0681	542	1.84502	293764	159220088	23.2809
488	2.04918	238144	116214272	22.0907	543	1.84162	294849	160103007	23.3024
489	2.04499	239121	116930169	22.1133	544	1.83824	295936	160989184	23.3238
490	2.04082	240100	117649000	22.1359	**545**	1.83486	297025	161878625	23.3452
491	2.03666	241081	118370771	22.1585	546	1.83150	298116	162771336	23.3666
492	2.03252	242064	119095488	22.1811	547	1.82815	299209	163667323	23.3880
493	2.02840	243049	119823157	22.2036	548	1.82482	300304	164566592	23.4094
494	2.02429	244036	120553784	22.2261	549	1.82149	301401	165469149	23.4307
495	2.02020	245025	121287375	22.2486	**550**	1.81818	302500	166375000	23.4521
496	2.01613	246016	122023936	22.2711	551	1.81488	303601	167284151	23.4734
497	2.01207	247009	122763473	22.2935	552	1.81159	304704	168196608	23.4947
498	2.00803	248004	123505992	22.3159	553	1.80832	305809	169112377	23.5160
499	2.00401	249001	124251499	22.3383	554	1.80505	306916	170031464	23.5372
500	2.00000	250000	125000000	22.3607	**555**	1.80180	308025	170953875	23.5584
501	1.99601	251001	125751501	22.3830	556	1.79856	309136	171879616	23.5797
502	1.99203	252004	126506008	22.4054	557	1.79533	310249	172808693	23.6008
503	1.98807	253009	127263527	22.4277	558	1.79211	311364	173741112	23.6220
504	1.98413	254016	128024064	22.4499	559	1.78891	312481	174676879	23.6432

VALUES OF RECIPROCALS, SQUARES, CUBES, AND SQUARE ROOTS OF NATURAL NUMBERS.

n	$1000.\frac{1}{n}$	n^2	n^3	$\sqrt{n}$	n	$1000.\frac{1}{n}$	n^2	n^3	$\sqrt{n}$
560	1.78571	313600	175616000	23.6643	**615**	1.62602	378225	232608375	24.7992
561	1.78253	314721	176558481	23.6854	616	1.62338	379456	233744896	24.8193
562	1.77936	315844	177504328	23.7065	617	1.62075	380689	234885113	24.8395
563	1.77620	316969	178453547	23.7276	618	1.61812	381924	236029032	24.8596
564	1.77305	318096	179406144	23.7487	619	1.61551	383161	237176659	24.8797
565	1.76991	319225	180362125	23.7697	**620**	1.61290	384400	238328000	24.8998
566	1.76678	320356	181321496	23.7908	621	1.61031	385641	239483061	24.9199
567	1.76367	321489	182284263	23.8118	622	1.60772	386884	240641848	24.9399
568	1.76056	322624	183250432	23.8328	623	1.60514	388129	241804367	24.9600
569	1.75747	323761	184220009	23.8537	624	1.60256	389376	242970624	24.9800
570	1.75439	324900	185193000	23.8747	**625**	1.60000	390625	244140625	25.0000
571	1.75131	326041	186169411	23.8956	626	1.59744	391876	245314376	25.0200
572	1.74825	327184	187149248	23.9165	627	1.59490	393129	246491883	25.0400
573	1.74520	328329	188132517	23.9374	628	1.59236	394384	247673152	25.0599
574	1.74216	329476	189119224	23.9583	629	1.58983	395641	248858189	25.0799
575	1.73913	330625	190109375	23.9792	**630**	1.58730	396900	250047000	25.0998
576	1.73611	331776	191102976	24.0000	631	1.58479	398161	251239591	25.1197
577	1.73310	332929	192100033	24.0208	632	1.58228	399424	252435968	25.1396
578	1.73010	334084	193100552	24.0416	633	1.57978	400689	253636137	25.1595
579	1.72712	335241	194104539	24.0624	634	1.57729	401956	254840104	25.1794
580	1.72414	336400	195112000	24.0832	**635**	1.57480	403225	256047875	25.1992
581	1.72117	337561	196122941	24.1039	636	1.57233	404496	257259456	25.2190
582	1.71821	338724	197137368	24.1247	637	1.56986	405769	258474853	25.2389
583	1.71527	339889	198155287	24.1454	638	1.56740	407044	259694072	25.2587
584	1.71233	341056	199176704	24.1661	639	1.56495	408321	260917119	25.2784
585	1.70940	342225	200201625	24.1868	**640**	1.56250	409600	262144000	25.2982
586	1.70648	343396	201230056	24.2074	641	1.56006	410881	263374721	25.3180
587	1.70358	344569	202262003	24.2281	642	1.55763	412164	264609288	25.3377
588	1.70068	345744	203297472	24.2487	643	1.55521	413449	265847707	25.3574
589	1.69779	346921	204336469	24.2693	644	1.55280	414736	267089984	25.3772
590	1.69492	348100	205379000	24.2899	**645**	1.55039	416025	268336125	25.3969
591	1.69205	349281	206425071	24.3105	646	1.54799	417316	269586136	25.4165
592	1.68919	350464	207474688	24.3311	647	1.54560	418609	270840023	25.4362
593	1.68634	351649	208527857	24.3516	648	1.54321	419904	272097792	25.4558
594	1.68350	352836	209584584	24.3721	649	1.54083	421201	273359449	25.4755
595	1.68067	354025	210644875	24.3926	**650**	1.53846	422500	274625000	25.4951
596	1.67785	355216	211708736	24.4131	651	1.53610	423801	275894451	25.5147
597	1.67504	356409	212776173	24.4336	652	1.53374	425104	277167808	25.5343
598	1.67224	357604	213847192	24.4540	653	1.53139	426409	278445077	25.5539
599	1.66945	358801	214921799	24.4745	654	1.52905	427716	279726264	25.5734
600	1.66667	360000	216000000	24.4949	**655**	1.52672	429025	281011375	25.5930
601	1.66389	361201	217081801	24.5153	656	1.52439	430336	282300416	25.6125
602	1.66113	362404	218167208	24.5357	657	1.52207	431649	283593393	25.6320
603	1.65837	363609	219256227	24.5561	658	1.51976	432964	284890312	25.6515
604	1.65563	364816	220348864	24.5764	659	1.51745	434281	286191179	25.6710
605	1.65289	366025	221445125	24.5967	**660**	1.51515	435600	287496000	25.6905
606	1.65017	367236	222545016	24.6171	661	1.51286	436921	288804781	25.7099
607	1.64745	368449	223648543	24.6374	662	1.51057	438244	290117528	25.7294
608	1.64474	369664	224755712	24.6577	663	1.50830	439569	291434247	25.7488
609	1.64204	370881	225866529	24.6779	664	1.50602	440896	292754944	25.7682
610	1.63934	372100	226981000	24.6982	**665**	1.50376	442225	294079625	25.7876
611	1.63666	373321	228099131	24.7184	666	1.50150	443556	295408296	25.8070
612	1.63399	374544	229220928	24.7386	667	1.49925	444889	296740963	25.8263
613	1.63132	375769	230346397	24.7588	668	1.49701	446224	298077632	25.8457
614	1.62866	376996	231475544	24.7790	669	1.49477	447561	299418309	25.8650

VALUES OF RECIPROCALS, SQUARES, CUBES, AND SQUARE ROOTS OF NATURAL NUMBERS.

n	$1000.\frac{1}{n}$	n^2	n^3	$\sqrt{n}$	n	$1000.\frac{1}{n}$	n^2	n^3	$\sqrt{n}$
670	1.49254	448900	300763000	25.8844	**725**	1.37931	525625	381078125	26.9258
671	1.49031	450241	302111711	25.9037	726	1.37741	527076	382657176	26.9444
672	1.48810	451584	303464448	25.9230	727	1.37552	528529	384240583	26.9629
673	1.48588	452929	304821217	25.9422	728	1.37363	529984	385828352	26.9815
674	1.48368	454276	306182024	25.9615	729	1.37174	531441	387420489	27.0000
675	1.48148	455625	307546875	25.9808	**730**	1.36986	532900	389017000	27.0185
676	1.47929	456976	308915776	26.0000	731	1.36799	534361	390617891	27.0370
677	1.47710	458329	310288733	26.0192	732	1.36612	535824	392223168	27.0555
678	1.47493	459684	311665752	26.0384	733	1.36426	537289	393832837	27.0740
679	1.47275	461041	313046839	26.0576	734	1.36240	538756	395446904	27.0924
680	1.47059	462400	314432000	26.0768	**735**	1.36054	540225	397065375	27.1109
681	1.46843	463761	315821241	26.0960	736	1.35870	541696	398688256	27.1293
682	1.46628	465124	317214568	26.1151	737	1.35685	543169	400315553	27.1477
683	1.46413	466489	318611987	26.1343	738	1.35501	544644	401947272	27.1662
684	1.46199	467856	320013504	26.1534	739	1.35318	546121	403583419	27.1846
685	1.45985	469225	321419125	26.1725	**740**	1.35135	547600	405224000	27.2029
686	1.45773	470596	322828856	26.1916	741	1.34953	549081	406869021	27.2213
687	1.45560	471969	324242703	26.2107	742	1.34771	550564	408518488	27.2397
688	1.45349	473344	325660672	26.2298	743	1.34590	552049	410172407	27.2580
689	1.45138	474721	327082769	26.2488	744	1.34409	553536	411830784	27.2764
690	1.44928	476100	328509000	26.2679	**745**	1.34228	555025	413493625	27.2947
691	1.44718	477481	329939371	26.2869	746	1.34048	556516	415160936	27.3130
692	1.44509	478864	331373888	26.3059	747	1.33869	558009	416832723	27.3313
693	1.44300	480249	332812557	26.3249	748	1.33690	559504	418508992	27.3496
694	1.44092	481636	334255384	26.3439	749	1.33511	561001	420189749	27.3679
695	1.43885	483025	335702375	26.3629	**750**	1.33333	562500	421875000	27.3861
696	1.43678	484416	337153536	26.3818	751	1.33156	564001	423564751	27.4044
697	1.43472	485809	338608873	26.4008	752	1.32979	565504	425259008	27.4226
698	1.43266	487204	340068392	26.4197	753	1.32802	567009	426957777	27.4408
699	1.43062	488601	341532099	26.4386	754	1.32626	568516	428661064	27.4591
700	1.42857	490000	343000000	26.4575	**755**	1.32450	570025	430368875	27.4773
701	1.42653	491401	344472101	26.4764	756	1.32275	571536	432081216	27.4955
702	1.42450	492804	345948408	26.4953	757	1.32100	573049	433798093	27.5136
703	1.42248	494209	347428927	26.5141	758	1.31926	574564	435519512	27.5318
704	1.42045	495616	348913664	26.5330	759	1.31752	576081	437245479	27.5500
705	1.41844	497025	350402625	26.5518	**760**	1.31579	577600	438976000	27.5681
706	1.41643	498436	351895816	26.5707	761	1.31406	579121	440711081	27.5862
707	1.41443	499849	353393243	26.5895	762	1.31234	580644	442450728	27.6043
708	1.41243	501264	354894912	26.6083	763	1.31062	582169	444194947	27.6225
709	1.41044	502681	356400829	26.6271	764	1.30890	583696	445943744	27.6405
710	1.40845	504100	357911000	26.6458	**765**	1.30719	585225	447697125	27.6586
711	1.40647	505521	359425431	26.6646	766	1.30548	586756	449455096	27.6767
712	1.40449	506944	360944128	26.6833	767	1.30378	588289	451217663	27.6948
713	1.40252	508369	362467097	26.7021	768	1.30208	589824	452984832	27.7128
714	1.40056	509796	363994344	26.7208	769	1.30039	591361	454756609	27.7308
715	1.39860	511225	365525875	26.7395	**770**	1.29870	592900	456533000	27.7489
716	1.39665	512656	367061696	26.7582	771	1.29702	594441	458314011	27.7669
717	1.39470	514089	368601813	26.7769	772	1.29534	595984	460099648	27.7849
718	1.39276	515524	370146232	26.7955	773	1.29366	597529	461889917	27.8029
719	1.39082	516961	371694959	26.8142	774	1.29199	599076	463684824	27.8209
720	1.38889	518400	373248000	26.8328	**775**	1.29032	600625	465484375	27.8388
721	1.38696	519841	374805361	26.8514	776	1.28866	602176	467288576	27.8568
722	1.38504	521284	376367048	26.8701	777	1.28700	603729	469097433	27.8747
723	1.38313	522729	377933067	26.8887	778	1.28535	605284	470910952	27.8927
724	1.38122	524176	379503424	26.9072	779	1.28370	606841	472729139	27.9106

VALUES OF RECIPROCALS, SQUARES, CUBES, AND SQUARE ROOTS OF NATURAL NUMBERS.

n	$1000.\frac{1}{n}$	n^2	n^3	$\sqrt{n}$	n	$1000.\frac{1}{n}$	n^2	n^3	$\sqrt{n}$
780	1.28205	608400	474552000	27.9285	**835**	1.19760	697225	582182875	28.8964
781	1.28041	609961	476379541	27.9464	836	1.19617	698896	584277056	28.9137
782	1.27877	611524	478211768	27.9643	837	1.19474	700569	586376253	28.9310
783	1.27714	613089	480048687	27.9821	838	1.19332	702244	588480472	28.9482
784	1.27551	614656	481890304	28.0000	839	1.19190	703921	590589719	28.9655
785	1.27389	616225	483736625	28.0179	**840**	1.19048	705600	592704000	28.9828
786	1.27226	617796	485587656	28.0357	841	1.18906	707281	594823321	29.0000
787	1.27065	619369	487443403	28.0535	842	1.18765	708964	596947688	29.0172
788	1.26904	620944	489303872	28.0713	843	1.18624	710649	599077107	29.0345
789	1.26743	622521	491169069	28.0891	844	1.18483	712336	601211584	29.0517
790	1.26582	624100	493039000	28.1069	**845**	1.18343	714025	603351125	29.0689
791	1.26422	625681	494913671	28.1247	846	1.18203	715716	605495736	29.0861
792	1.26263	627264	496793088	28.1425	847	1.18064	717409	607645423	29.1033
793	1.26103	628849	498677257	28.1603	848	1.17925	719104	609800192	29.1204
794	1.25945	630436	500566184	28.1780	849	1.17786	720801	611960049	29.1376
795	1.25786	632025	502459875	28.1957	**850**	1.17647	722500	614125000	29.1548
796	1.25628	633616	504358336	28.2135	851	1.17509	724201	616295051	29.1719
797	1.25471	635209	506261573	28.2312	852	1.17371	725904	618470208	29.1890
798	1.25313	636804	508169592	28.2489	853	1.17233	727609	620650477	29.2062
799	1.25156	638401	510082399	28.2666	854	1.17096	729316	622835864	29.2233
800	1.25000	640000	512000000	28.2843	**855**	1.16959	731025	625026375	29.2404
801	1.24844	641601	513922401	28.3019	856	1.16822	732736	627222016	29.2575
802	1.24688	643204	515849608	28.3196	857	1.16686	734449	629422793	29.2746
803	1.24533	644809	517781627	28.3373	858	1.16550	736164	631628712	29.2916
804	1.24378	646416	519718464	28.3549	859	1.16414	737881	633839779	29.3087
805	1.24224	648025	521660125	28.3725	**860**	1.16279	739600	636056000	29.3258
806	1.24069	649636	523606616	28.3901	861	1.16144	741321	638277381	29.3428
807	1.23916	651249	525557943	28.4077	862	1.16009	743044	640503928	29.3598
808	1.23762	652864	527514112	28.4253	863	1.15875	744769	642735647	29.3769
809	1.23609	654481	529475129	28.4429	864	1.15741	746496	644972544	29.3939
810	1.23457	656100	531441000	28.4605	**865**	1.15607	748225	647214625	29.4109
811	1.23305	657721	533411731	28.4781	866	1.15473	749956	649461896	29.4279
812	1.23153	659344	535387328	28.4956	867	1.15340	751689	651714363	29.4449
813	1.23001	660969	537367797	28.5132	868	1.15207	753424	653972032	29.4618
814	1.22850	662596	539353144	28.5307	869	1.15075	755161	656234909	29.4788
815	1.22699	664225	541343375	28.5482	**870**	1.14943	756900	658503000	29.4958
816	1.22549	665856	543338496	28.5657	871	1.14811	758641	660776311	29.5127
817	1.22399	667489	545338513	28.5832	872	1.14679	760384	663054848	29.5296
818	1.22249	669124	547343432	28.6007	873	1.14548	762129	665338617	29.5466
819	1.22100	670761	549353259	28.6182	874	1.14416	763876	667627624	29.5635
820	1.21951	672400	551368000	28.6356	**875**	1.14286	765625	669921875	29.5804
821	1.21803	674041	553387661	28.6531	876	1.14155	767376	672221376	29.5973
822	1.21655	675684	555412248	28.6705	877	1.14025	769129	674526133	29.6142
823	1.21507	677329	557441767	28.6880	878	1.13895	770884	676836152	29.6311
824	1.21359	678976	559476224	28.7054	879	1.13766	772641	679151439	29.6479
825	1.21212	680625	561515625	28.7228	**880**	1.13636	774400	681472000	29.6648
826	1.21065	682276	563559976	28.7402	881	1.13507	776161	683797841	29.6816
827	1.20919	683929	565609283	28.7576	882	1.13379	777924	686128968	29.6985
828	1.20773	685584	567663552	28.7750	883	1.13250	779689	688465387	29.7153
829	1.20627	687241	569722789	28.7924	884	1.13122	781456	690807104	29.7321
830	1.20482	688900	571787000	28.8097	**885**	1.12994	783225	693154125	29.7489
831	1.20337	690561	573856191	28.8271	886	1.12867	784996	695506456	29.7658
832	1.20192	692224	575930368	28.8444	887	1.12740	786769	697864103	29.7825
833	1.20048	693889	578009537	28.8617	888	1.12613	788544	700227072	29.7993
834	1.19904	695556	580093704	28.8791	889	1.12486	790321	702595369	29.8161

VALUES OF RECIPROCALS, SQUARES, CUBES, AND SQUARE ROOTS OF NATURAL NUMBERS.

n	$1000.\frac{1}{n}$	n^2	n^3	$\sqrt{n}$	n	$1000.\frac{1}{n}$	n^2	n^3	$\sqrt{n}$
890	1.12360	792100	704969000	29.8329	**945**	1.05820	893025	843908625	30.7409
891	1.12233	793881	707347971	29.8496	946	1.05708	894916	846590536	30.7571
892	1.12108	795664	709732288	29.8664	947	1.05597	896809	849278123	30.7734
893	1.11982	797449	712121957	29.8831	948	1.05485	898704	851971392	30.7896
894	1.11857	799236	714516984	29.8998	949	1.05374	900601	854670349	30.8058
895	1.11732	801025	716917375	29.9166	**950**	1.05263	902500	857375000	30.8221
896	1.11607	802816	719323136	29.9333	951	1.05152	904401	860085351	30.8383
897	1.11483	804609	721734273	29.9500	952	1.05042	906304	862801408	30.8545
898	1.11359	806404	724150792	29.9666	953	1.04932	908209	865523177	30.8707
899	1.11235	808201	726572699	29.9833	954	1.04822	910116	868250664	30.8869
900	1.11111	810000	729000000	30.0000	**955**	1.04712	912025	870983875	30.9031
901	1.10988	811801	731432701	30.0167	956	1.04603	913936	873722816	30.9192
902	1.10865	813604	733870808	30.0333	957	1.04493	915849	876467493	30.9354
903	1.10742	815409	736314327	30.0500	958	1.04384	917764	879217912	30.9516
904	1.10619	817216	738763264	30.0666	959	1.04275	919681	881974079	30.9677
905	1.10497	819025	741217625	30.0832	**960**	1.04167	921600	884736000	30.9839
906	1.10375	820836	743677416	30.0998	961	1.04058	923521	887503681	31.0000
907	1.10254	822649	746142643	30.1164	962	1.03950	925444	890277128	31.0161
908	1.10132	824464	748613312	30.1330	963	1.03842	927369	893056347	31.0322
909	1.10011	826281	751089429	30.1496	964	1.03734	929296	895841344	31.0483
910	1.09890	828100	753571000	30.1662	**965**	1.03627	931225	898632125	31.0644
911	1.09769	829921	756058031	30.1828	966	1.03520	933156	901428696	31.0805
912	1.09649	831744	758550528	30.1993	967	1.03413	935089	904231063	31.0966
913	1.09529	833569	761048497	30.2159	968	1.03306	937024	907039232	31.1127
914	1.09409	835396	763551944	30.2324	969	1.03199	938961	909853209	31.1288
915	1.09290	837225	766060875	30.2490	**970**	1.03093	940900	912673000	31.1448
916	1.09170	839056	768575296	30.2655	971	1.02987	942841	915498611	31.1609
917	1.09051	840889	771095213	30.2820	972	1.02881	944784	918330048	31.1769
918	1.08932	842724	773620632	30.2985	973	1.02775	946729	921167317	31.1929
919	1.08814	844561	776151559	30.3150	974	1.02669	948676	924010424	31.2090
920	1.08696	846400	778688000	30.3315	**975**	1.02564	950625	926859375	31.2250
921	1.08578	848241	781229961	30.3480	976	1.02459	952576	929714176	31.2410
922	1.08460	850084	783777448	30.3645	977	1.02354	954529	932574833	31.2570
923	1.08342	851929	786330467	30.3809	978	1.02249	956484	935441352	31.2730
924	1.08225	853776	788889024	30.3974	979	1.02145	958441	938313739	31.2890
925	1.08108	855625	791453125	30.4138	**980**	1.02041	960400	941192000	31.3050
926	1.07991	857476	794022776	30.4302	981	1.01937	962361	944076141	31.3209
927	1.07875	859329	796597983	30.4467	982	1.01833	964324	946966168	31.3369
928	1.07759	861184	799178752	30.4631	983	1.01729	966289	949862087	31.3528
929	1.07643	863041	801765089	30.4795	984	1.01626	968256	952763904	31.3688
930	1.07527	864900	804357000	30.4959	**985**	1.01523	970225	955671625	31.3847
931	1.07411	866761	806954491	30.5123	986	1.01420	972196	958585256	31.4006
932	1.07296	868624	809557568	30.5287	987	1.01317	974169	961504803	31.4166
933	1.07181	870489	812166237	30.5450	988	1.01215	976144	964430272	31.4325
934	1.07066	872356	814780504	30.5614	989	1.01112	978121	967361669	31.4484
935	1.06952	874225	817400375	30.5778	**990**	1.01010	980100	970299000	31.4643
936	1.06838	876096	820025856	30.5941	991	1.00908	982081	973242271	31.4802
937	1.06724	877969	822656953	30.6105	992	1.00806	984064	976191488	31.4960
938	1.06610	879844	825293672	30.6268	993	1.00705	986049	979146657	31.5119
939	1.06496	881721	827936019	30.6431	994	1.00604	988036	982107784	31.5278
940	1.06383	883600	830584000	30.6594	**995**	1.00503	990025	985074875	31.5436
941	1.06270	885481	833237621	30.6757	996	1.00402	992016	988047936	31.5595
942	1.06157	887364	835896888	30.6920	997	1.00301	994009	991026973	31.5753
943	1.06045	889249	838561807	30.7083	998	1.00200	996004	994011992	31.5911
944	1.05932	891136	841232384	30.7246	999	1.00100	998001	997002999	31.6070

	0	1	2	3	4	5	6	7	8	9	10
05	0000	0004	0009	0013	0017	0022	0026	0030	0035	0039	0043
06	0043	0048	0052	0056	0060	0065	0069	0073	0077	0082	0086
07	0086	0090	0095	0099	0103	0107	0111	0116	0120	0124	0128
08	0128	0133	0137	0141	0145	0149	0154	0158	0162	0166	0170
09	0170	0175	0179	0183	0187	0191	0195	0199	0204	0208	0212
10	0212	0216	0220	0224	0228	0233	0237	0241	0245	0249	0253
11	0253	0257	0261	0265	0269	0273	0278	0282	0286	0290	0294
12	0294	0298	0302	0306	0310	0314	0318	0322	0326	0330	0334
13	0334	0338	0342	0346	0350	0354	0358	0362	0366	0370	0374
14	0374	0378	0382	0386	0390	0394	0398	0402	0406	0410	0414
15	0414	0418	0422	0426	0430	0434	0438	0441	0445	0449	0453
16	0453	0457	0461	0465	0469	0473	0477	0481	0484	0488	0492
17	0492	0496	0500	0504	0508	0512	0515	0519	0523	0527	0531
18	0531	0535	0538	0542	0546	0550	0554	0558	0561	0565	0569
19	0569	0573	0577	0580	0584	0588	0592	0596	0599	0603	0607
20	0607	0611	0615	0618	0622	0626	0630	0633	0637	0641	0645
21	0645	0648	0652	0656	0660	0663	0667	0671	0674	0678	0682
22	0682	0686	0689	0693	0697	0700	0704	0708	0711	0715	0719
23	0719	0722	0726	0730	0734	0737	0741	0745	0748	0752	0755
24	0755	0759	0763	0766	0770	0774	0777	0781	0785	0788	0792
25	0792	0795	0799	0803	0806	0810	0813	0817	0821	0824	0828
26	0828	0831	0835	0839	0842	0846	0849	0853	0856	0860	0864
27	0864	0867	0871	0874	0878	0881	0885	0888	0892	0896	0899
28	0899	0903	0906	0910	0913	0917	0920	0924	0927	0931	0934
29	0934	0938	0941	0945	0948	0952	0955	0959	0962	0966	0969
30	0969	0973	0976	0980	0983	0986	0990	0993	0997	1000	1004
31	1004	1007	1011	1014	1017	1021	1024	1028	1031	1035	1038
32	1038	1041	1045	1048	1052	1055	1059	1062	1065	1069	1072
33	1072	1075	1079	1082	1086	1089	1092	1096	1099	1103	1106
34	1106	1109	1113	1116	1119	1123	1126	1129	1133	1136	1139
35	1139	1143	1146	1149	1153	1156	1159	1163	1166	1169	1173
36	1173	1176	1179	1183	1186	1189	1193	1196	1199	1202	1206
37	1206	1209	1212	1216	1219	1222	1225	1229	1232	1235	1239
38	1239	1242	1245	1248	1252	1255	1258	1261	1265	1268	1271
39	1271	1274	1278	1281	1284	1287	1290	1294	1297	1300	1303
40	1303	1307	1310	1313	1316	1319	1323	1326	1329	1332	1335
41	1335	1339	1342	1345	1348	1351	1355	1358	1361	1364	1367
42	1367	1370	1374	1377	1380	1383	1386	1389	1392	1396	1399
43	1399	1402	1405	1408	1411	1414	1418	1421	1424	1427	1430
44	1430	1433	1436	1440	1443	1446	1449	1452	1455	1458	1461
45	1461	1464	1467	1471	1474	1477	1480	1483	1486	1489	1492
46	1492	1495	1498	1501	1504	1508	1511	1514	1517	1520	1523
47	1523	1526	1529	1532	1535	1538	1541	1544	1547	1550	1553
48	1553	1556	1559	1562	1565	1569	1572	1575	1578	1581	1584
49	1584	1587	1590	1593	1596	1599	1602	1605	1608	1611	1614
50	1614	1617	1620	1623	1626	1629	1632	1635	1638	1641	1644
51	1644	1647	1649	1652	1655	1658	1661	1664	1667	1670	1673
52	1673	1676	1679	1682	1685	1688	1691	1694	1697	1700	1703
53	1703	1706	1708	1711	1714	1717	1720	1723	1726	1729	1732
54	1732	1735	1738	1741	1744	1746	1749	1752	1755	1758	1761

	0	1	2	3	4	5	6	7	8	9	10
	1761	1764	1767	1770	1772	1775	1778	1781	1784	1787	1790
	1790	1793	1796	1798	1801	1804	1807	1810	1813	1816	1818
	1818	1821	1824	1827	1830	1833	1836	1838	1841	1844	1847
	1847	1850	1853	1855	1858	1861	1864	1867	1870	1872	1875
	1875	1878	1881	1884	1886	1889	1892	1895	1898	1901	1903
	1903	1906	1909	1912	1915	1917	1920	1923	1926	1928	1931
	1931	1934	1937	1940	1942	1945	1948	1951	1953	1956	1959
	1959	1962	1965	1967	1970	1973	1976	1978	1981	1984	1987
	1987	1989	1992	1995	1998	2000	2003	2006	2009	2011	2014
	2014	2017	2019	2022	2025	2028	2030	2033	2036	2038	2041
60	2041	2044	2047	2049	2052	2055	2057	2060	2063	2066	2068
161	2068	2071	2074	2076	2079	2082	2084	2087	2090	2092	2095
162	2095	2098	2101	2103	2106	2109	2111	2114	2117	2119	2122
163	2122	2125	2127	2130	2133	2135	2138	2140	2143	2146	2148
164	2148	2151	2154	2156	2159	2162	2164	2167	2170	2172	2175
165	2175	2177	2180	2183	2185	2188	2191	2193	2196	2198	2201
166	2201	2204	2206	2209	2212	2214	2217	2219	2222	2225	2227
167	2227	2230	2232	2235	2238	2240	2243	2245	2248	2251	2253
168	2253	2256	2258	2261	2263	2266	2269	2271	2274	2276	2279
169	2279	2281	2284	2287	2289	2292	2294	2297	2299	2302	2304
170	2304	2307	2310	2312	2315	2317	2320	2322	2325	2327	2330
171	2330	2333	2335	2338	2340	2343	2345	2348	2350	2353	2355
172	2355	2358	2360	2363	2365	2368	2370	2373	2375	2378	2380
173	2380	2383	2385	2388	2390	2393	2395	2398	2400	2403	2405
174	2405	2408	2410	2413	2415	2418	2420	2423	2425	2428	2430
175	2430	2433	2435	2438	2440	2443	2445	2448	2450	2453	2455
176	2455	2458	2460	2463	2465	2467	2470	2472	2475	2477	2480
177	2480	2482	2485	2487	2490	2492	2494	2497	2499	2502	2504
178	2504	2507	2509	2512	2514	2516	2519	2521	2524	2526	2529
179	2529	2531	2533	2536	2538	2541	2543	2545	2548	2550	2553
180	2553	2555	2558	2560	2562	2565	2567	2570	2572	2574	2577
181	2577	2579	2582	2584	2586	2589	2591	2594	2596	2598	2601
182	2601	2603	2605	2608	2610	2613	2615	2617	2620	2622	2625
183	2625	2627	2629	2632	2634	2636	2639	2641	2643	2646	2648
184	2648	2651	2653	2655	2658	2660	2662	2665	2667	2669	2672
185	2672	2674	2676	2679	2681	2683	2686	2688	2690	2693	2695
186	2695	2697	2700	2702	2704	2707	2709	2711	2714	2716	2718
187	2718	2721	2723	2725	2728	2730	2732	2735	2737	2739	2742
188	2742	2744	2746	2749	2751	2753	2755	2758	2760	2762	2765
189	2765	2767	2769	2772	2774	2776	2778	2781	2783	2785	2788
190	2788	2790	2792	2794	2797	2799	2801	2804	2806	2808	2810
191	2810	2813	2815	2817	2819	2822	2824	2826	2828	2831	2833
192	2833	2835	2838	2840	2842	2844	2847	2849	2851	2853	2856
193	2856	2858	2860	2862	2865	2867	2869	2871	2874	2876	2878
194	2878	2880	2882	2885	2887	2889	2891	2894	2896	2898	2900
195	2900	2903	2905	2907	2909	2911	2914	2916	2918	2920	2923
196	2923	2925	2927	2929	2931	2934	2936	2938	2940	2942	2945
197	2945	2947	2949	2951	2953	2956	2958	2960	2962	2964	2967
198	2967	2969	2971	2973	2975	2978	2980	2982	2984	2986	2989
199	2989	2991	2993	2995	2997	2999	3002	3004	3006	3008	3010

LOGARITHMS.

N	0	1	2	3	4	5	6	7	8	9	P. P.				
											1	2	3	4	5
10	0000	0043	0086	0128	0170	0212	0253	0294	0334	0374	4	8	12	17	21
11	0414	0453	0492	0531	0569	0607	0645	0682	0719	0755	4	8	11	15	19
12	0792	0828	0864	0899	0934	0969	1004	1038	1072	1106	3	7	10	14	17
13	1139	1173	1206	1239	1271	1303	1335	1367	1399	1430	3	6	10	13	16
14	1461	1492	1523	1553	1584	1614	1644	1673	1703	1732	3	6	9	12	15
15	1761	1790	1818	1847	1875	1903	1931	1959	1987	2014	3	6	8	11	14
16	2041	2068	2095	2122	2148	2175	2201	2227	2253	2270	3	5	8	11	13
17	2304	2330	2355	2380	2405	2430	2455	2480	2504	2529	2	5	7	10	12
18	2553	2577	2601	2625	2648	2672	2695	2718	2742	2765	2	5	7	9	12
19	2788	2810	2833	2856	2878	2900	2923	2945	2967	2989	2	4	7	9	11
20	3010	3032	3054	3075	3096	3118	3139	3160	3181	3201	2	4	6	8	11
21	3222	3243	3263	3284	3304	3324	3345	3365	3385	3404	2	4	6	8	10
22	3424	3444	3464	3483	3502	3522	3541	3560	3579	3598	2	4	6	8	10
23	3617	3636	3655	3674	3692	3711	3729	3747	3766	3784	2	4	5	7	9
24	3802	3820	3838	3856	3874	3892	3909	3927	3945	3962	2	4	5	7	9
25	3979	3997	4014	4031	4048	4065	4082	4099	4116	4133	2	3	5	7	9
26	4150	4166	4183	4200	4216	4232	4249	4265	4281	4298	2	3	5	7	8
27	4314	4330	4346	4362	4378	4393	4409	4425	4440	4456	2	3	5	6	8
28	4472	4487	4502	4518	4533	4548	4564	4579	4594	4609	2	3	5	6	8
29	4624	4639	4654	4669	4683	4698	4713	4728	4742	4757	1	3	4	6	7
30	4771	4786	4800	4814	4829	4843	4857	4871	4886	4900	1	3	4	6	7
31	4914	4928	4942	4955	4969	4983	4997	5011	5024	5038	1	3	4	6	7
32	5051	5065	5079	5092	5105	5119	5132	5145	5159	5172	1	3	4	5	7
33	5185	5198	5211	5224	5237	5250	5263	5276	5289	5302	1	3	4	5	6
34	5315	5328	5340	5353	5366	5378	5391	5403	5416	5428	1	3	4	5	6
35	5441	5453	5465	5478	5490	5502	5514	5527	5539	5551	1	2	4	5	6
36	5563	5575	5587	5599	5611	5623	5635	5647	5658	5670	1	2	4	5	6
37	5682	5694	5705	5717	5729	5740	5752	5763	5775	5786	1	2	3	5	6
38	5798	5809	5821	5832	5843	5855	5866	5877	5888	5899	1	2	3	5	6
39	5911	5922	5933	5944	5955	5966	5977	5988	5999	6010	1	2	3	4	6
40	6021	6031	6042	6053	6064	6075	6085	6096	6107	6117	1	2	3	4	5
41	6128	6138	6149	6160	6170	6180	6191	6201	6212	6222	1	2	3	4	5
42	6232	6243	6253	6263	6274	6284	6294	6304	6314	6325	1	2	3	4	5
43	6335	6345	6355	6365	6375	6385	6395	6405	6415	6425	1	2	3	4	5
44	6435	6444	6454	6464	6474	6484	6493	6503	6513	6522	1	2	3	4	5
45	6532	6542	6551	6561	6571	6580	6590	6599	6609	6618	1	2	3	4	5
46	6628	6637	6646	6656	6665	6675	6684	6693	6702	6712	1	2	3	4	5
47	6721	6730	6739	6749	6758	6767	6776	6785	6794	6803	1	2	3	4	5
48	6812	6821	6830	6839	6848	6857	6866	6875	6884	6893	1	2	3	4	4
49	6902	6911	6920	6928	6937	6946	6955	6964	6972	6981	1	2	3	4	4
50	6990	6998	7007	7016	7024	7033	7042	7050	7059	7067	1	2	3	3	4
51	7076	7084	7093	7101	7110	7118	7126	7135	7143	7152	1	2	3	3	4
52	7160	7168	7177	7185	7193	7202	7210	7218	7226	7235	1	2	2	3	4
53	7243	7251	7259	7267	7275	7284	7292	7300	7308	7316	1	2	2	3	4
54	7324	7332	7340	7348	7356	7364	7372	7380	7388	7396	1	2	2	3	4

1	2	3	4	5	6	7	8	9	P. P. 1	2	3	4	5
7412	7419	7427	7435	7443	7451	7459	7466	7474	1	2	2	3	4
7490	7497	7505	7513	7520	7528	7535	7543	7551	1	2	2	3	4
7566	7574	7582	7589	7597	7604	7612	7619	7627	1	2	2	3	4
7642	7649	7657	7664	7672	7679	7686	7694	7701	1	1	2	3	4
7716	7723	7731	7738	7745	7752	7760	7767	7774	1	1	2	3	4
7789	7796	7803	7810	7818	7825	7832	7839	7846	1	1	2	3	4
7860	7868	7875	7882	7889	7896	7903	7910	7917	1	1	2	3	4
7931	7938	7945	7952	7959	7966	7973	7980	7987	1	1	2	3	3
8000	8007	8014	8021	8028	8035	8041	8048	8055	1	1	2	3	3
8069	8075	8082	8089	8096	8102	8109	8116	8122	1	1	2	3	3
8136	8142	8149	8156	8162	8169	8176	8182	8189	1	1	2	3	3
8202	8209	8215	8222	8228	8235	8241	8248	8254	1	1	2	3	3
8267	8274	8280	8287	8293	8299	8306	8312	8319	1	1	2	3	3
8331	8338	8344	8351	8357	8363	8370	8376	8382	1	1	2	3	3
8395	8401	8407	8414	8420	8426	8432	8439	8445	1	1	2	3	3
8457	8463	8470	8476	8482	8488	8494	8500	8506	1	1	2	2	3
8519	8525	8531	8537	8543	8549	8555	8561	8567	1	1	2	2	3
8579	8585	8591	8597	8603	8609	8615	8621	8627	1	1	2	2	3
8639	8645	8651	8657	8663	8669	8675	8681	8686	1	1	2	2	3
8698	8704	8710	8716	8722	8727	8733	8739	8745	1	1	2	2	3
8756	8762	8768	8774	8779	8785	8791	8797	8802	1	1	2	2	3
8814	8820	8825	8831	8837	8842	8848	8854	8859	1	1	2	2	3
8871	8876	8882	8887	8893	8899	8904	8910	8915	1	1	2	2	3
8927	8932	8938	8943	8949	8954	8960	8965	8971	1	1	2	2	3
8982	8987	8993	8998	9004	9009	9015	9020	9025	1	1	2	2	3
9036	9042	9047	9053	9058	9063	9069	9074	9079	1	1	2	2	3
9090	9096	9101	9106	9112	9117	9122	9128	9133	1	1	2	2	3
9143	9149	9154	9159	9165	9170	9175	9180	9186	1	1	2	2	3
9196	9201	9206	9212	9217	9222	9227	9232	9238	1	1	2	2	3
9248	9253	9258	9263	9269	9274	9279	9284	9289	1	1	2	2	3
9299	9304	9309	9315	9320	9325	9330	9335	9340	1	1	2	2	3
9350	9355	9360	9365	9370	9375	9380	9385	9390	1	1	2	2	3
9400	9405	9410	9415	9420	9425	9430	9435	9440	0	1	1	2	2
9450	9455	9460	9465	9469	9474	9479	9484	9489	0	1	1	2	2
9499	9504	9509	9513	9518	9523	9528	9533	9538	0	1	1	2	2
9547	9552	9557	9562	9566	9571	9576	9581	9586	0	1	1	2	2
9595	9600	9605	9609	9614	9619	9624	9628	9633	0	1	1	2	2
9643	9647	9652	9657	9661	9666	9671	9675	9680	0	1	1	2	2
9689	9694	9699	9703	9708	9713	9717	9722	9727	0	1	1	2	2
9736	9741	9745	9750	9754	9759	9763	9768	9773	0	1	1	2	2
9782	9786	9791	9795	9800	9805	9809	9814	9818	0	1	1	2	2
9827	9832	9836	9841	9845	9850	9854	9859	9863	0	1	1	2	2
9872	9877	9881	9886	9890	9894	9899	9903	9908	0	1	1	2	2
9917	9921	9926	9930	9934	9939	9943	9948	9952	0	1	1	2	2
9961	9965	9969	9974	9978	9983	9987	9991	9996	0	1	1	2	2

TABLE 9.

ANTILOGARITHMS.

	0	1	2	3	4	5	6	7	8	9	P. P.				
											1	2	3	4	5
.00	1000	1002	1005	1007	1009	1012	1014	1016	1019	1021	0	0	1	1	1
.01	1023	1026	1028	1030	1033	1035	1038	1040	1042	1045	0	0	1	1	1
.02	1047	1050	1052	1054	1057	1059	1062	1064	1067	1069	0	0	1	1	1
.03	1072	1074	1076	1079	1081	1084	1086	1089	1091	1094	0	0	1	1	1
.04	1096	1099	1102	1104	1107	1109	1112	1114	1117	1119	0	1	1	1	1
.05	1122	1125	1127	1130	1132	1135	1138	1140	1143	1146	0	1	1	1	1
.06	1148	1151	1153	1156	1159	1161	1164	1167	1169	1172	0	1	1	1	1
.07	1175	1178	1180	1183	1186	1189	1191	1194	1197	1199	0	1	1	1	1
.08	1202	1205	1208	1211	1213	1216	1219	1222	1225	1227	0	1	1	1	1
.09	1230	1233	1236	1239	1242	1245	1247	1250	1253	1256	0	1	1	1	1
.10	1259	1262	1265	1268	1271	1274	1276	1279	1282	1285	0	1	1	1	1
.11	1288	1291	1294	1297	1300	1303	1306	1309	1312	1315	0	1	1	1	2
.12	1318	1321	1324	1327	1330	1334	1337	1340	1343	1346	0	1	1	1	2
.13	1349	1352	1355	1358	1361	1365	1368	1371	1374	1377	0	1	1	1	2
.14	1380	1384	1387	1390	1393	1396	1400	1403	1406	1409	0	1	1	1	2
.15	1413	1416	1419	1422	1426	1429	1432	1435	1439	1442	0	1	1	1	2
.16	1445	1449	1452	1455	1459	1462	1466	1469	1472	1476	0	1	1	1	2
.17	1479	1483	1486	1489	1493	1496	1500	1503	1507	1510	0	1	1	1	2
.18	1514	1517	1521	1524	1528	1531	1535	1538	1542	1545	0	1	1	1	2
.19	1549	1552	1556	1560	1563	1567	1570	1574	1578	1581	0	1	1	1	2
.20	1585	1589	1592	1596	1600	1603	1607	1611	1614	1618	0	1	1	1	2
.21	1622	1626	1629	1633	1637	1641	1644	1648	1652	1656	0	1	1	2	2
.22	1660	1663	1667	1671	1675	1679	1683	1687	1690	1694	0	1	1	2	2
.23	1698	1702	1706	1710	1714	1718	1722	1726	1730	1734	0	1	1	2	2
.24	1738	1742	1746	1750	1754	1758	1762	1766	1770	1774	0	1	1	2	2
.25	1778	1782	1786	1791	1795	1799	1803	1807	1811	1816	0	1	1	2	2
.26	1820	1824	1828	1832	1837	1841	1845	1849	1854	1858	0	1	1	2	2
.27	1862	1866	1871	1875	1879	1884	1888	1892	1897	1901	0	1	1	2	2
.28	1905	1910	1914	1919	1923	1928	1932	1936	1941	1945	0	1	1	2	2
.29	1950	1954	1959	1963	1968	1972	1977	1982	1986	1991	0	1	1	2	2
.30	1995	2000	2004	2009	2014	2018	2023	2028	2032	2037	0	1	1	2	2
.31	2042	2046	2051	2056	2061	2065	2070	2075	2080	2084	0	1	1	2	2
.32	2089	2094	2099	2104	2109	2113	2118	2123	2128	2133	0	1	1	2	2
.33	2138	2143	2148	2153	2158	2163	2168	2173	2178	2183	0	1	1	2	2
.34	2188	2193	2198	2203	2208	2213	2218	2223	2228	2234	1	1	2	2	3
.35	2239	2244	2249	2254	2259	2265	2270	2275	2280	2286	1	1	2	2	3
.36	2291	2296	2301	2307	2312	2317	2323	2328	2333	2339	1	1	2	2	3
.37	2344	2350	2355	2360	2366	2371	2377	2382	2388	2393	1	1	2	2	3
.38	2399	2404	2410	2415	2421	2427	2432	2438	2443	2449	1	1	2	2	3
.39	2455	2460	2466	2472	2477	2483	2489	2495	2500	2506	1	1	2	2	3
.40	2512	2518	2523	2529	2535	2541	2547	2553	2559	2564	1	1	2	2	3
.41	2570	2576	2582	2588	2594	2600	2606	2612	2618	2624	1	1	2	2	3
.42	2630	2636	2642	2649	2655	2661	2667	2673	2679	2685	1	1	2	2	3
.43	2692	2698	2704	2710	2716	2723	2729	2735	2742	2748	1	1	2	3	3
.44	2754	2761	2767	2773	2780	2786	2793	2799	2805	2812	1	1	2	3	3
.45	2818	2825	2831	2838	2844	2851	2858	2864	2871	2877	1	1	2	3	3
.46	2884	2891	2897	2904	2911	2917	2924	2931	2938	2944	1	1	2	3	3
.47	2951	2958	2965	2972	2979	2985	2992	2999	3006	3013	1	1	2	3	3
.48	3020	3027	3034	3041	3048	3055	3062	3069	3076	3083	1	1	2	3	4
.49	3090	3097	3105	3112	3119	3126	3133	3141	3148	3155	1	1	2	3	4

ANTILOGARITHMS.

	0	1	2	3	4	5	6	7	8	9	P. P.				
											1	2	3	4	5
.50	3162	3170	3177	3184	3192	3199	3206	3214	3221	3228	1	1	2	3	4
.51	3236	3243	3251	3258	3266	3273	3281	3289	3296	3304	1	2	2	3	4
.52	3311	3319	3327	3334	3342	3350	3357	3365	3373	3381	1	2	2	3	4
.53	3388	3396	3404	3412	3420	3428	3436	3443	3451	3459	1	2	2	3	4
.54	3467	3475	3483	3491	3499	3508	3516	3524	3532	3540	1	2	2	3	4
.55	3548	3556	3565	3573	3581	3589	3597	3606	3614	3622	1	2	2	3	4
.56	3631	3639	3648	3656	3664	3673	3681	3690	3698	3707	1	2	3	3	4
.57	3715	3724	3733	3741	3750	3758	3767	3776	3784	3793	1	2	3	3	4
.58	3802	3811	3819	3828	3837	3846	3855	3864	3873	3882	1	2	3	4	4
.59	3890	3899	3908	3917	3926	3936	3945	3954	3963	3972	1	2	3	4	5
.60	3981	3990	3999	4009	4018	4027	4036	4046	4055	4064	1	2	3	4	5
.61	4074	4083	4093	4102	4111	4121	4130	4140	4150	4159	1	2	3	4	5
.62	4169	4178	4188	4198	4207	4217	4227	4236	4246	4256	1	2	3	4	5
.63	4266	4276	4285	4295	4305	4315	4325	4335	4345	4355	1	2	3	4	5
.64	4365	4375	4385	4395	4406	4416	4426	4436	4446	4457	1	2	3	4	5
.65	4467	4477	4487	4498	4508	4519	4529	4539	4550	4560	1	2	3	4	5
.66	4571	4581	4592	4603	4613	4624	4634	4645	4656	4667	1	2	3	4	5
.67	4677	4688	4699	4710	4721	4732	4742	4753	4764	4775	1	2	3	4	5
.68	4786	4797	4808	4819	4831	4842	4853	4864	4875	4887	1	2	3	4	6
.69	4898	4909	4920	4932	4943	4955	4966	4977	4989	5000	1	2	3	5	6
.70	5012	5023	5035	5047	5058	5070	5082	5093	5105	5117	1	2	4	5	6
.71	5129	5140	5152	5164	5176	5188	5200	5212	5224	5236	1	2	4	5	6
.72	5248	5260	5272	5284	5297	5309	5321	5333	5346	5358	1	2	4	5	6
.73	5370	5383	5395	5408	5420	5433	5445	5458	5470	5483	1	3	4	5	6
.74	5495	5508	5521	5534	5546	5559	5572	5585	5598	5610	1	3	4	5	6
.75	5623	5636	5649	5662	5675	5689	5702	5715	5728	5741	1	3	4	5	7
.76	5754	5768	5781	5794	5808	5821	5834	5848	5861	5875	1	3	4	5	7
.77	5888	5902	5916	5929	5943	5957	5970	5984	5998	6012	1	3	4	5	7
.78	6026	6039	6053	6067	6081	6095	6109	6124	6138	6152	1	3	4	6	7
.79	6166	6180	6194	6209	6223	6237	6252	6266	6281	6295	1	3	4	6	7
.80	6310	6324	6339	6353	6368	6383	6397	6412	6427	6442	1	3	4	6	7
.81	6457	6471	6486	6501	6516	6531	6546	6561	6577	6592	2	3	5	6	8
.82	6607	6622	6637	6653	6668	6683	6699	6714	6730	6745	2	3	5	6	8
.83	6761	6776	6792	6808	6823	6839	6855	6871	6887	6902	2	3	5	6	8
.84	6918	6934	6950	6966	6982	6998	7015	7031	7047	7063	2	3	5	6	8
.85	7079	7096	7112	7129	7145	7161	7178	7194	7211	7228	2	3	5	7	8
.86	7244	7261	7278	7295	7311	7328	7345	7362	7379	7396	2	3	5	7	8
.87	7413	7430	7447	7464	7482	7499	7516	7534	7551	7568	2	3	5	7	9
.88	7586	7603	7621	7638	7656	7674	7691	7709	7727	7745	2	4	5	7	9
.89	7762	7780	7798	7816	7834	7852	7870	7889	7907	7925	2	4	5	7	9
.90	7943	7962	7980	7998	8017	8035	8054	8072	8091	8110	2	4	6	7	9
.91	8128	8147	8166	8185	8204	8222	8241	8260	8279	8299	2	4	6	8	9
.92	8318	8337	8356	8375	8395	8414	8433	8453	8472	8492	2	4	6	8	10
.93	8511	8531	8551	8570	8590	8610	8630	8650	8670	8690	2	4	6	8	10
.94	8710	8730	8750	8770	8790	8810	8831	8851	8872	8892	2	4	6	8	10
.95	8913	8933	8954	8974	8995	9016	9036	9057	9078	9099	2	4	6	8	10
.96	9120	9141	9162	9183	9204	9226	9247	9268	9290	9311	2	4	6	8	11
.97	9333	9354	9376	9397	9419	9441	9462	9484	9506	9528	2	4	7	9	11
.98	9550	9572	9594	9616	9638	9661	9683	9705	9727	9750	2	4	7	9	11
.99	9772	9795	9817	9840	9863	9886	9908	9931	9954	9977	2	5	7	9	11

TABLE 10.

ANTILOGARITHMS.

	0	1	2	3	4	5	6	7	8	9	10
.900	7943	7945	7947	7949	7951	7952	7954	7956	7958	7960	7962
.901	7962	7963	7965	7967	7969	7971	7973	7974	7976	7978	7980
.902	7980	7982	7984	7985	7987	7989	7991	7993	7995	7997	7998
.903	7998	8000	8002	8004	8006	8008	8009	8011	8013	8015	8017
.904	8017	8019	8020	8022	8024	8026	8028	8030	8032	8033	8035
.905	8035	8037	8039	8041	8043	8045	8046	8048	8050	8052	8054
.906	8054	8056	8057	8059	8061	8063	8065	8067	8069	8070	8072
.907	8072	8074	8076	8078	8080	8082	8084	8085	8087	8089	8091
.908	8091	8093	8095	8097	8098	8100	8102	8104	8106	8108	8110
.909	8110	8111	8113	8115	8117	8119	8121	8123	8125	8126	8128
.910	8128	8130	8132	8134	8136	8138	8140	8141	8143	8145	8147
.911	8147	8149	8151	8153	8155	8156	8158	8168	8162	8164	8166
.912	8166	8168	8170	8171	8173	8175	8177	8179	8181	8183	8185
.913	8185	8187	8188	8190	8192	8194	8196	8198	8200	8202	8204
.914	8204	8205	8207	8209	8211	8213	8215	8217	8219	8221	8222
.915	8222	8224	8226	8228	8230	8232	8234	8236	8238	8239	8241
.916	8241	8243	8245	8247	8249	8251	8253	8255	8257	8258	8260
.917	8260	8262	8264	8266	8268	8270	8272	8274	8276	8278	8279
.918	8279	8281	8283	8285	8287	8289	8291	8293	8295	8297	8299
.919	8299	8300	8302	8304	8306	8308	8310	8312	8314	8316	8318
.920	8318	8320	8321	8323	8325	8327	8329	8331	8333	8335	8337
.921	8337	8339	8341	8343	8344	8346	8348	8350	8352	8354	8356
.922	8356	8358	8360	8362	8364	8366	8368	8370	8371	8373	8375
.923	8375	8377	8379	8381	8383	8385	8387	8389	8391	8393	8395
.924	8395	8397	8398	8400	8402	8404	8406	8408	8410	8412	8414
.925	8414	8416	8418	8420	8422	8424	8426	8428	8429	8431	8433
.926	8433	8435	8437	8439	8441	8443	8445	8447	8449	8451	8453
.927	8453	8455	8457	8459	8461	8463	8464	8466	8468	8470	8472
.928	8472	8474	8476	8478	8480	8482	8484	8486	8488	8490	8492
.929	8492	8494	8496	8498	8500	8502	8504	8506	8507	8509	8511
.930	8511	8513	8515	8517	8519	8521	8523	8525	8527	8529	8531
.931	8531	8533	8535	8537	8539	8541	8543	8545	8547	8549	8551
.932	8551	8553	8555	8557	8559	8561	8562	8564	8566	8568	8570
.933	8570	8572	8574	8576	8578	8580	8582	8584	8586	8588	8590
.934	8590	8592	8594	8596	8598	8600	8602	8604	8606	8608	8610
.935	8610	8612	8614	8616	8618	8620	8622	8624	8626	8628	8630
.936	8630	8632	8634	8636	8638	8640	8642	8644	8646	8648	8650
.937	8650	8652	8654	8656	8658	8660	8662	8664	8666	8668	8670
.938	8670	8672	8674	8676	8678	8680	8682	8684	8686	8688	8690
.939	8690	8692	8694	8696	8698	8700	8702	8704	8706	8708	8710
.940	8710	8712	8714	8716	8718	8720	8722	8724	8726	8728	8730
.941	8730	8732	8734	8736	8738	8740	8742	8744	8746	8748	8750
.942	8750	8752	8754	8756	8758	8760	8762	8764	8766	8768	8770
.943	8770	8772	8774	8776	8778	8780	8782	8784	8786	8788	8790
.944	8790	8792	8794	8796	8798	8800	8802	8804	8806	8808	8810
.945	8810	8813	8815	8817	8819	8821	8823	8825	8827	8829	8831
.946	8831	8833	8835	8837	8839	8841	8843	8845	8847	8849	8851
.947	8851	8853	8855	8857	8859	8861	8863	8865	8867	8870	8872
.948	8872	8874	8876	8878	8880	8882	8884	8886	8888	8890	8892
.949	8892	8894	8896	8898	8900	8902	8904	8906	8908	8910	8913

ANTILOGARITHMS.

	0	1	2	3	4	5	6	7	8	9	10
.950	8913	8915	8917	8919	8921	8923	8925	8927	8929	8931	8933
.951	8933	8935	8937	8939	8941	8943	8945	8947	8950	8952	8954
.952	8954	8956	8958	8960	8962	8964	8966	8968	8970	8972	8974
.953	8974	8976	8978	8980	8983	8985	8987	8989	8991	8993	8995
.954	8995	8997	8999	9001	9003	9005	9007	9009	9012	9014	9016
.955	9016	9018	9020	9022	9024	9026	9028	9030	9032	9034	9036
.956	9036	9039	9041	9043	9045	9047	9049	9051	9053	9055	9057
.957	9057	9059	9061	9064	9066	9068	9070	9072	9074	9076	9078
.958	9078	9080	9082	9084	9087	9089	9091	9093	9095	9097	9099
.959	9099	9101	9103	9105	9108	9110	9112	9114	9116	9118	9120
.960	9120	9122	9124	9126	9129	9131	9133	9135	9137	9139	9141
.961	9141	9143	9145	9147	9150	9152	9154	9156	9158	9160	9162
.962	9162	9164	9166	9169	9171	9173	9175	9177	9179	9181	9183
.963	9183	9185	9188	9190	9192	9194	9196	9198	9200	9202	9204
.964	9204	9207	9209	9211	9213	9215	9217	9219	9221	9224	9226
.965	9226	9228	9230	9232	9234	9236	9238	9241	9243	9245	9247
.966	9247	9249	9251	9253	9256	9258	9260	9262	9264	9266	9268
.967	9268	9270	9273	9275	9277	9279	9281	9283	9285	9288	9290
.968	9290	9292	9294	9296	9298	9300	9303	9305	9307	9309	9311
.969	9311	9313	9315	9318	9320	9322	9324	9326	9328	9330	9333
.970	9333	9335	9337	9339	9341	9343	9345	9348	9350	9352	9354
.971	9354	9356	9358	9361	9363	9365	9367	9369	9371	9373	9376
.972	9376	9378	9380	9382	9384	9386	9389	9391	9393	9395	9397
.973	9397	9399	9402	9404	9406	9408	9410	9412	9415	9417	9419
.974	9419	9421	9423	9425	9428	9430	9432	9434	9436	9438	9441
.975	9441	9443	9445	9447	9449	9451	9454	9456	9458	9460	9462
.976	9462	9465	9467	9469	9471	9473	9475	9478	9480	9482	9484
.977	9484	9486	9489	9491	9493	9495	9497	9499	9502	9504	9506
.978	9506	9508	9510	9513	9515	9517	9519	9521	9524	9526	9528
.979	9528	9530	9532	9535	9537	9539	9541	9543	9546	9548	9550
.980	9550	9552	9554	9557	9559	9561	9563	9565	9568	9570	9572
.981	9572	9574	9576	9579	9581	9583	9585	9587	9590	9592	9594
.982	9594	9596	9598	9601	9603	9605	9607	9609	9612	9614	9616
.983	9616	9618	9621	9623	9625	9627	9629	9632	9634	9636	9638
.984	9638	9641	9643	9645	9647	9649	9652	9654	9656	9658	9661
.985	9661	9663	9665	9667	9669	9672	9674	9676	9678	9681	9683
.986	9683	9685	9687	9689	9692	9694	9696	9698	9701	9703	9705
.987	9705	9707	9710	9712	9714	9716	9719	9721	9723	9725	9727
.988	9727	9730	9732	9734	9736	9739	9741	9743	9745	9748	9750
.989	9750	9752	9754	9757	9759	9761	9763	9766	9768	9770	9772
.990	9772	9775	9777	9779	9781	9784	9786	9788	9790	9793	9795
.991	9795	9797	9799	9802	9804	9806	9808	9811	9813	9815	9817
.992	9817	9820	9822	9824	9827	9829	9831	9833	9836	9838	9840
.993	9840	9842	9845	9847	9849	9851	9854	9856	9858	9861	9863
.994	9863	9865	9867	9870	9872	9874	9876	9879	9881	9883	9886
.995	9886	9888	9890	9892	9895	9897	9899	9901	9904	9906	9908
.996	9908	9911	9913	9915	9917	9920	9922	9924	9927	9929	9931
.997	9931	9933	9936	9938	9940	9943	9945	9947	9949	9952	9954
.998	9954	9956	9959	9961	9963	9966	9968	9970	9972	9975	9977
.999	9977	9979	9982	9984	9986	9988	9991	9993	9995	9998	0000

TABLE 11.

CIRCULAR (TRIGONOMETRIC) FUNCTIONS.

(Taken from B. O. Peirce's "Short Table of Integrals," Ginn & Co.)

RADIANS.	DEGREES.	SINES. Nat.	SINES. Log.	COSINES. Nat.	COSINES. Log.	TANGENTS. Nat.	TANGENTS. Log.	COTANGENTS. Nat.	COTANGENTS. Log.	DEGREES.	RADIANS.
0.0000	0°00′	.0000	∞	1.0000	0.0000	.0000	∞	∞	∞	90°00′	1.5708
0.0029	10	.0029	7.4637	1.0000	.0000	.0029	7.4637	343.77	2.5363	50	1.5679
0.0058	20	.0058	.7648	1.0000	.0000	.0058	.7648	171.89	.2352	40	1.5650
0.0087	30	.0087	.9408	1.0000	.0000	.0087	.9409	114.59	.0591	30	1.5621
0.0116	40	.0116	8.0658	.9999	.0000	.0116	8.0658	85.940	1.9342	20	1.5592
0.0145	50	.0145	.1627	.9999	.0000	.0145	.1627	68.750	.8373	10	1.5563
0.0175	1°00′	.0175	8.2419	.9998	9.9999	.0175	8.2419	57.290	1.7581	89°00′	1.5533
0.0204	10	.0204	.3088	.9998	.9999	.0204	.3089	49.104	.6911	50	1.5504
0.0233	20	.0233	.3668	.9997	.9999	.0233	.3669	42.964	.6331	40	1.5475
0.0262	30	.0262	.4179	.9997	.9999	.0262	.4181	38.188	.5819	30	1.5446
0.0291	40	.0291	.4637	.9996	.9998	.0291	.4638	34.368	.5362	20	1.5417
0.0320	50	.0320	.5050	.9995	.9998	.0320	.5053	31.242	.4947	10	1.5388
0.0349	2°00′	.0349	8.5428	.9994	9.9997	.0349	8.5431	28.636	1.4569	88°00′	1.5359
0.0378	10	.0378	.5776	.9993	.9997	.0378	.5779	26.432	.4221	50	1.5330
0.0407	20	.0407	.6097	.9992	.9996	.0407	.6101	24.542	.3899	40	1.5301
0.0436	30	.0436	.6397	.9990	.9996	.0437	.6401	22.904	.3599	30	1.5272
0.0465	40	.0465	.6677	.9989	.9995	.0466	.6682	21.470	.3318	20	1.5243
0.0495	50	.0494	.6940	.9988	.9995	.0495	.6945	20.206	.3055	10	1.5213
0.0524	3°00′	.0523	8.7188	.9986	9.9994	.0524	8.7194	19.081	1.2806	87°00′	1.5184
0.0553	10	.0552	.7423	.9985	.9993	.0553	.7429	18.075	.2571	50	1.5155
0.0582	20	.0581	.7645	.9983	.9993	.0582	.7652	17.169	.2348	40	1.5126
0.0611	30	.0610	.7857	.9981	.9992	.0612	.7865	16.350	.2135	30	1.5097
0.0640	40	.0640	.8059	.9980	.9991	.0641	.8067	15.605	.1933	20	1.5068
0.0669	50	.0669	.8251	.9978	.9990	.0670	.8261	14.924	.1739	10	1.5039
0.0698	4°00′	.0698	8.8436	.9976	9.9989	.0699	8.8446	14.301	1.1554	86°00′	1.5010
0.0727	10	.0727	.8613	.9974	.9989	.0729	.8624	13.727	.1376	50	1.4981
0.0756	20	.0756	.8783	.9971	.9988	.0758	.8795	13.197	.1205	40	1.4952
0.0785	30	.0785	.8946	.9969	.9987	.0787	.8960	12.706	.1040	30	1.4923
0.0814	40	.0814	.9104	.9967	.9986	.0816	.9118	12.251	.0882	20	1.4893
0.0844	50	.0843	.9256	.9964	.9985	.0846	.9272	11.826	.0728	10	1.4864
0.0873	5°00′	.0872	8.9403	.9962	9.9983	.0875	8.9420	11.430	1.0580	85°00′	1.4835
0.0902	10	.0901	.9545	.9959	.9982	.0904	.9563	11.059	.0437	50	1.4806
0.0931	20	.0929	.9682	.9957	.9981	.0934	.9701	10.712	.0299	40	1.4777
0.0960	30	.0958	.9816	.9954	.9980	.0963	.9836	10.385	.0164	30	1.4748
0.0989	40	.0987	.9945	.9951	.9979	.0992	.9966	10.078	.0034	20	1.4719
0.1018	50	.1016	9.0070	.9948	.9977	.1022	9.0093	9.7882	0.9907	10	1.4690
0.1047	6°00	.1045	9.0192	.9945	9.9976	.1051	9.0216	9.5144	0.9784	84°00′	1.4661
0.1076	10	.1074	.0311	.9942	.9975	.1080	.0336	9.2553	.9664	50	1.4632
0.1105	20	.1103	.0426	.9939	.9973	.1110	.0453	9.0098	.9547	40	1.4603
0.1134	30	.1132	.0539	.9936	.9972	.1139	.0567	8.7769	.9433	30	1.4574
0.1164	40	.1161	.0648	.9932	.9971	.1169	.0678	8.5555	.9322	20	1.4544
0.1193	50	.1190	.0755	.9929	.9969	.1198	.0786	8.3450	.9214	10	1.4515
0.1222	7°00′	.1219	9.0859	.9925	9.9968	.1228	9.0891	8.1443	0.9109	83°00′	1.4486
0.1251	10	.1248	.0961	.9922	.9966	.1257	.0995	7.9530	.9005	50	1.4457
0.1280	20	.1276	.1060	.9918	.9964	.1287	.1096	7.7704	.8904	40	1.4428
0.1309	30	.1305	.1157	.9914	.9963	.1317	.1194	7.5958	.8806	30	1.4399
0.1338	40	.1334	.1252	.9911	.9961	.1346	.1291	7.4287	.8709	20	1.4370
0.1367	50	.1363	.1345	.9907	.9959	.1376	.1385	7.2687	.8615	10	1.4341
0.1396	8°00′	.1392	9.1436	.9903	9.9958	.1405	9.1478	7.1154	0.8522	82°00′	1.4312
0.1425	10	.1421	.1525	.9899	.9956	.1435	.1569	6.9682	.8431	50	1.4283
0.1454	20	.1449	.1612	.9894	.9954	.1465	.1658	6.8269	.8342	40	1.4254
0.1484	30	.1478	.1697	.9890	.9952	.1495	.1745	6.6912	.8255	30	1.4224
0.1513	40	.1507	.1781	.9886	.9950	.1524	.1831	6.5606	.8169	20	1.4195
0.1542	50	.1536	.1863	.9881	.9948	.1554	.1915	6.4348	.8085	10	1.4166
0.1571	9°00′	.1564	9.1943	.9877	9.9946	.1584	9.1997	6.3138	0.8003	81°00′	1.4137
		Nat.	Log.	Nat.	Log.	Nat.	Log.	Nat.	Log.	DEGREES.	RADIANS.
		COSINES.		SINES.		COTANGENTS.		TANGENTS.			

CIRCULAR (TRIGONOMETRIC) FUNCTIONS.

RADIANS.	DEGREES.	SINES. Nat.	SINES. Log.	COSINES. Nat.	COSINES. Log.	TANGENTS. Nat.	TANGENTS. Log.	COTANGENTS. Nat.	COTANGENTS. Log.		
0.1571	9°00′	.1564	9.1943	.9877	9.9946	.1584	9.1997	6.3138	0.8003	81°00′	1.4137
0.1600	10	.1593	.2022	.9872	.9944	.1614	.2078	6.1970	.7922	50	1.4108
0.1629	20	.1622	.2100	.9868	.9942	.1644	.2158	6.0844	.7842	40	1.4079
0.1658	30	.1650	.2176	.9863	.9940	.1673	.2236	5.9758	.7764	30	1.4050
0.1687	40	.1679	.2251	.9858	.9938	.1703	.2313	5.8708	.7687	20	1.4021
0.1716	50	.1708	.2324	.9853	.9936	.1733	.2389	5.7694	.7611	10	1.3992
0.1745	10°00′	.1736	9.2397	.9848	9.9934	.1763	9.2463	5.6713	0.7537	80°00′	1.3963
0.1774	10	.1765	.2468	.9843	.9931	.1793	.2536	5.5764	.7464	50	1.3934
0.1804	20	.1794	.2538	.9838	.9929	.1823	.2609	5.4845	.7391	40	1.3904
0.1833	30	.1822	.2606	.9833	.9927	.1853	.2680	5.3955	.7320	30	1.3875
0.1862	40	.1851	.2674	.9827	.9924	.1883	.2750	5.3093	.7250	20	1.3846
0.1891	50	.1880	.2740	.9822	.9922	.1914	.2819	5.2257	.7181	10	1.3817
0.1920	11°00′	.1908	9.2806	.9816	9.9919	.1944	9.2887	5.1446	0.7113	79°00′	1.3788
0.1949	10	.1937	.2870	.9811	.9917	.1974	.2953	5.0658	.7047	50	1.3759
0.1978	20	.1965	.2934	.9805	.9914	.2004	.3020	4.9894	.6980	40	1.3730
0.2007	30	.1994	.2997	.9799	.9912	.2035	.3085	4.9152	.6915	30	1.3701
0.2036	40	.2022	.3058	.9793	.9909	.2065	.3149	4.8430	.6851	20	1.3672
0.2065	50	.2051	.3119	.9787	.9907	.2095	.3212	4.7729	.6788	10	1.3643
0.2094	12°00′	.2079	9.3179	.9781	9.9904	.2126	9.3275	4.7046	0.6725	78°00′	1.3614
0.2123	10	.2108	.3238	.9775	.9901	.2156	.3336	4.6382	.6664	50	1.3584
0.2153	20	.2136	.3296	.9769	.9899	.2186	.3397	4.5736	.6603	40	1.3555
0.2182	30	.2164	.3353	.9763	.9896	.2217	.3458	4.5107	.6542	30	1.3526
0.2211	40	.2193	.3410	.9757	.9893	.2247	.3517	4.4494	.6483	20	1.3497
0.2240	50	.2221	.3466	.9750	.9890	.2278	.3576	4.3897	.6424	10	1.3468
0.2269	13°00′	.2250	9.3521	.9744	9.9887	.2309	9.3634	4.3315	0.6366	77°00′	1.3439
0.2298	10	.2278	.3575	.9737	.9884	.2339	.3691	4.2747	.6309	50	1.3410
0.2327	20	.2306	.3629	.9730	.9881	.2370	.3748	4.2193	.6252	40	1.3381
0.2356	30	.2334	.3682	.9724	.9878	.2401	.3804	4.1653	.6196	30	1.3352
0.2385	40	.2363	.3734	.9717	.9875	.2432	.3859	4.1126	.6141	20	1.3323
0.2414	50	.2391	.3786	.9710	.9872	.2462	.3914	4.0611	.6086	10	1.3294
0.2443	14°00′	.2419	9.3837	.9703	9.9869	.2493	9.3968	4.0108	0.6032	76°00′	1.3265
0.2473	10	.2447	.3887	.9696	.9866	.2524	.4021	3.9617	.5979	50	1.3235
0.2502	20	.2476	.3937	.9689	.9863	.2555	.4074	3.9136	.5926	40	1.3206
0.2531	30	.2504	.3986	.9681	.9859	.2586	.4127	3.8667	.5873	30	1.3177
0.2560	40	.2532	.4035	.9674	.9856	.2617	.4178	3.8208	.5822	20	1.3148
0.2589	50	.2560	.4083	.9667	.9853	.2648	.4230	3.7760	.5770	10	1.3119
0.2618	15°00′	.2588	9.4130	.9659	9.9849	.2679	9.4281	3.7321	0.5719	75°00′	1.3090
0.2647	10	.2616	.4177	.9652	.9846	.2711	.4331	3.6891	.5669	50	1.3061
0.2676	20	.2644	.4223	.9644	.9843	.2742	.4381	3.6470	.5619	40	1.3032
0.2705	30	.2672	.4269	.9636	.9839	.2773	.4430	3.6059	.5570	30	1.3003
0.2734	40	.2700	.4314	.9628	.9836	.2805	.4479	3.5656	.5521	20	1.2974
0.2763	50	.2728	.4359	.9621	.9832	.2836	.4527	3.5261	.5473	10	1.2945
0.2793	16°00′	.2756	9.4403	.9613	9.9828	.2867	9.4575	3.4874	0.5425	74°00′	1.2915
0.2822	10	.2784	.4447	.9605	.9825	.2899	.4622	3.4495	.5378	50	1.2886
0.2851	20	.2812	.4491	.9596	.9821	.2931	.4669	3.4124	.5331	40	1.2857
0.2880	30	.2840	.4533	.9588	.9817	.2962	.4716	3.3759	.5284	30	1.2828
0.2909	40	.2868	.4576	.9580	.9814	.2994	.4762	3.3402	.5238	20	1.2799
0.2938	50	.2896	.4618	.9572	.9810	.3026	.4808	3.3052	.5192	10	1.2770
0.2967	17°00′	.2924	9.4659	.9563	9.9806	.3057	9.4853	3.2709	0.5147	73°00′	1.2741
0.2996	10	.2952	.4700	.9555	.9802	.3089	.4898	3.2371	.5102	50	1.2712
0.3025	20	.2979	.4741	.9546	.9798	.3121	.4943	3.2041	.5057	40	1.2683
0.3054	30	.3007	.4781	.9537	.9794	.3153	.4987	3.1716	.5013	30	1.2654
0.3083	40	.3035	.4821	.9528	.9790	.3185	.5031	3.1397	.4969	20	1.2625
0.3113	50	.3062	.4861	.9520	.9786	.3217	.5075	3.1084	.4925	10	1.2595
0.3142	18°00′	.3090	9.4900	.9511	9.9782	.3249	9.5118	3.0777	0.4882	72°00′	1.2566
		Nat.	Log.	Nat.	Log.	Nat.	Log.	Nat.	Log.	DEGREES.	RADIANS.
		COSINES.		SINES.		COTANGENTS.		TANGENTS.			

CIRCULAR (TRIGONOMETRIC) FUNCTIONS.

RADIANS.	DEGREES.	SINES. Nat.	SINES. Log.	COSINES. Nat.	COSINES. Log.	TANGENTS. Nat.	TANGENTS. Log.	COTANGENTS. Nat.	COTANGENTS. Log.		
0.3142	18°00′	.3090	9.4900	.9511	9.9782	.3249	9.5118	3.0777	0.4882	72°00′	1.2566
0.3171	10	.3118	.4939	.9502	.9778	.3281	.5161	3.0475	.4839	50	1.2537
0.3200	20	.3145	.4977	.9492	.9774	.3314	.5203	3.0178	.4797	40	1.2508
0.3229	30	.3173	.5015	.9483	.9770	.3346	.5245	2.9887	.4755	30	1.2479
0.3258	40	.3201	.5052	.9474	.9765	.3378	.5287	2.9600	.4713	20	1.2450
0.3287	50	.3228	.5090	.9465	.9761	.3411	.5329	2.9319	.4671	10	1.2421
0.3316	19°00′	.3256	9.5126	.9455	9.9757	.3443	9.5370	2.9042	0.4630	71°00′	1.2392
0.3345	10	.3283	.5163	.9446	.9752	.3476	.5411	2.8770	.4589	50	1.2363
0.3374	20	.3311	.5199	.9436	.9748	.3508	.5451	2.8502	.4549	40	1.2334
0.3403	30	.3338	.5235	.9426	.9743	.3541	.5491	2.8239	.4509	30	1.2305
0.3432	40	.3365	.5270	.9417	.9739	.3574	.5531	2.7980	.4469	20	1.2275
0.3462	50	.3393	.5306	.9407	.9734	.3607	.5571	2.7725	.4429	10	1.2246
0.3491	20°00′	.3420	9.5341	.9397	9.9730	.3640	9.5611	2.7475	0.4389	70°00′	1.2217
0.3520	10	.3448	.5375	.9387	.9725	.3673	.5650	2.7228	.4350	50	1.2188
0.3549	20	.3475	.5409	.9377	.9721	.3706	.5689	2.6985	.4311	40	1.2159
0.3578	30	.3502	.5443	.9367	.9716	.3739	.5727	2.6746	.4273	30	1.2130
0.3607	40	.3529	.5477	.9356	.9711	.3772	.5766	2.6511	.4234	20	1.2101
0.3636	50	.3557	.5510	.9346	.9706	.3805	.5804	2.6279	.4196	10	1.2072
0.3665	21°00′	.3584	9.5543	.9336	9.9702	.3839	9.5842	2.6051	0.4158	69°00′	1.2043
0.3694	10	.3611	.5576	.9325	.9697	.3872	.5879	2.5826	.4121	50	1.2014
0.3723	20	.3638	.5609	.9315	.9692	.3906	.5917	2.5605	.4083	40	1.1985
0.3752	30	.3665	.5641	.9304	.9687	.3939	.5954	2.5386	.4046	30	1.1956
0.3782	40	.3692	.5673	.9293	.9682	.3973	.5991	2.5172	.4009	20	1.1926
0.3811	50	.3719	.5704	.9283	.9677	.4006	.6028	2.4960	.3972	10	1.1897
0.3840	22°00′	.3746	9.5736	.9272	9.9672	.4040	9.6064	2.4751	0.3936	68°00′	1.1868
0.3869	10	.3773	.5767	.9261	.9667	.4074	.6100	2.4545	.3900	50	1.1839
0.3898	20	.3800	.5798	.9250	.9661	.4108	.6136	2.4342	.3864	40	1.1810
0.3927	30	.3827	.5828	.9239	.9656	.4142	.6172	2.4142	.3828	30	1.1781
0.3956	40	.3854	.5859	.9228	.9651	.4176	.6208	2.3945	.3792	20	1.1752
0.3985	50	.3881	.5889	.9216	.9646	.4210	.6243	2.3750	.3757	10	1.1723
0.4014	23°00′	.3907	9.5919	.9205	9.9640	.4245	9.6279	2.3559	0.3721	67°00′	1.1694
0.4043	10	.3934	.5948	.9194	.9635	.4279	.6314	2.3369	.3686	50	1.1665
0.4072	20	.3961	.5978	.9182	.9629	.4314	.6348	2.3183	.3652	40	1.1636
0.4102	30	.3987	.6007	.9171	.9624	.4348	.6383	2.2998	.3617	30	1.1606
0.4131	40	.4014	.6036	.9159	.9618	.4383	.6417	2.2817	.3583	20	1.1577
0.4160	50	.4041	.6065	.9147	.9613	.4417	.6452	2.2637	.3548	10	1.1548
0.4189	24°00′	.4067	9.6093	.9135	9.9607	.4452	9.6486	2.2460	0.3514	66°00′	1.1519
0.4218	10	.4094	.6121	.9124	.9602	.4487	.6520	2.2286	.3480	50	1.1490
0.4247	20	.4120	.6149	.9112	.9596	.4522	.6553	2.2113	.3447	40	1.1461
0.4276	30	.4147	.6177	.9100	.9590	.4557	.6587	2.1943	.3413	30	1.1432
0.4305	40	.4173	.6205	.9088	.9584	.4592	.6620	2.1775	.3380	20	1.1403
0.4334	50	.4200	.6232	.9075	.9579	.4628	.6654	2.1609	.3346	10	1.1374
0.4363	25°00′	.4226	9.6259	.9063	9.9573	.4663	9.6687	2.1445	0.3313	65°00′	1.1345
0.4392	10	.4253	.6286	.9051	.9567	.4699	.6720	2.1283	.3280	50	1.1316
0.4422	20	.4279	.6313	.9038	.9561	.4734	.6752	2.1123	.3248	40	1.1286
0.4451	30	.4305	.6340	.9026	.9555	.4770	.6785	2.0965	.3215	30	1.1257
0.4480	40	.4331	.6366	.9013	.9549	.4806	.6817	2.0809	.3183	20	1.1228
0.4509	50	.4358	.6392	.9001	.9543	.4841	.6850	2.0655	.3150	10	1.1199
0.4538	26°00′	.4384	9.6418	.8988	9.9537	.4877	9.6882	2.0503	0.3118	64°00′	1.1170
0.4567	10	.4410	.6444	.8975	.9530	.4913	.6914	2.0353	.3086	50	1.1141
0.4596	20	.4436	.6470	.8962	.9524	.4950	.6946	2.0204	.3054	40	1.1112
0.4625	30	.4462	.6495	.8949	.9518	.4986	.6977	2.0057	.3023	30	1.1083
0.4654	40	.4488	.6521	.8936	.9512	.5022	.7009	1.9912	.2991	20	1.1054
0.4683	50	.4514	.6546	.8923	.9505	.5059	.7040	1.9768	.2960	10	1.1025
0.4712	27°00′	.4540	9.6570	.8910	9.9499	.5095	9.7072	1.9626	0.2928	63°00′	1.0996
		Nat.	Log.	Nat.	Log.	Nat.	Log.	Nat.	Log.	DEGREES.	RADIANS.
		COSINES.		SINES.		COTANGENTS.		TANGENTS.			

RADIANS.	DEGREES.	SINES. Nat.	SINES. Log.	COSINES. Nat.	COSINES. Log.	TANGENTS. Nat.	TANGENTS. Log.	COTANGENTS. Nat.	COTANGENTS. Log.		
0.4712	27°00′	.4540	9.6570	.8910	9.9499	.5095	9.7072	1.9626	0.2928	63°00′	1.0996
0.4741	10	.4566	.6595	.8897	.9492	.5132	.7103	1.9486	.2897	50	1.0966
0.4771	20	.4592	.6620	.8884	.9486	.5169	.7134	1.9347	.2866	40	1.0937
0.4800	30	.4617	.6644	.8870	.9479	.5206	.7165	1.9210	.2835	30	1.0908
0.4829	40	.4643	.6668	.8857	.9473	.5243	.7196	1.9074	.2804	20	1.0879
0.4858	50	.4669	.6692	.8843	.9466	.5280	.7226	1.8940	.2774	10	1.0850
0.4887	28°00′	.4695	9.6716	.8829	9.9459	.5317	9.7257	1.8807	0.2743	62°00′	1.0821
0.4916	10	.4720	.6740	.8816	.9453	.5354	.7287	1.8676	.2713	50	1.0792
0.4945	20	.4746	.6763	.8802	.9446	.5392	.7317	1.8546	.2683	40	1.0763
0.4974	30	.4772	.6787	.8788	.9439	.5430	.7348	1.8418	.2652	30	1.0734
0.5003	40	.4797	.6810	.8774	.9432	.5467	.7378	1.8291	.2622	20	1.0705
0.5032	50	.4823	.6833	.8760	.9425	.5505	.7408	1.8165	.2592	10	1.0676
0.5061	29°00′	.4848	9.6856	.8746	9.9418	.5543	9.7438	1.8040	0.2562	61°00′	1.0647
0.5091	10	.4874	.6878	.8732	.9411	.5581	.7467	1.7917	.2533	50	1.0617
0.5120	20	.4899	.6901	.8718	.9404	.5619	.7497	1.7796	.2503	40	1.0588
0.5149	30	.4924	.6923	.8704	.9397	.5658	.7526	1.7675	.2474	30	1.0559
0.5178	40	.4950	.6946	.8689	.9390	.5696	.7556	1.7556	.2444	20	1.0530
0.5207	50	.4975	.6968	.8675	.9383	.5735	.7585	1.7437	.2415	10	1.0501
0.5236	30°00′	.5000	9.6990	.8660	9.9375	.5774	9.7614	1.7321	0.2386	60°00′	1.0472
0.5265	10	.5025	.7012	.8646	.9368	.5812	.7644	1.7205	.2356	50	1.0443
0.5294	20	.5050	.7033	.8631	.9361	.5851	.7673	1.7090	.2327	40	1.0414
0.5323	30	.5075	.7055	.8616	.9353	.5890	.7701	1.6977	.2299	30	1.0385
0.5352	40	.5100	.7076	.8601	.9346	.5930	.7730	1.6864	.2270	20	1.0356
0.5381	50	.5125	.7097	.8587	.9338	.5969	.7759	1.6753	.2241	10	1.0327
0.5411	31°00′	.5150	9.7118	.8572	9.9331	.6009	9.7788	1.6643	0.2212	59°00′	1.0297
0.5440	10	.5175	.7139	.8557	.9323	.6048	.7816	1.6534	.2184	50	1.0268
0.5469	20	.5200	.7160	.8542	.9315	.6088	.7845	1.6426	.2155	40	1.0239
0.5498	30	.5225	.7181	.8526	.9308	.6128	.7873	1.6319	.2127	30	1.0210
0.5527	40	.5250	.7201	.8511	.9300	.6168	.7902	1.6212	.2098	20	1.0181
0.5556	50	.5275	.7222	.8496	.9292	.6208	.7930	1.6107	.2070	10	1.0152
0.5585	32°00′	.5299	9.7242	.8480	9.9284	.6249	9.7958	1.6003	0.2042	58°00′	1.0123
0.5614	10	.5324	.7262	.8465	.9276	.6289	.7986	1.5900	.2014	50	1.0094
0.5643	20	.5348	.7282	.8450	.9268	.6330	.8014	1.5798	.1986	40	1.0065
0.5672	30	.5373	.7302	.8434	.9260	.6371	.8042	1.5697	.1958	30	1.0036
0.5701	40	.5398	.7322	.8418	.9252	.6412	.8070	1.5597	.1930	20	1.0007
0.5730	50	.5422	.7342	.8403	.9244	.6453	.8097	1.5497	.1903	10	0.9977
0.5760	33°00′	.5446	9.7361	.8387	9.9236	.6494	9.8125	1.5399	0.1875	57°00′	0.9948
0.5789	10	.5471	.7380	.8371	.9228	.6536	.8153	1.5301	.1847	50	0.9919
0.5818	20	.5495	.7400	.8355	.9219	.6577	.8180	1.5204	.1820	40	0.9890
0.5847	30	.5519	.7419	.8339	.9211	.6619	.8208	1.5108	.1792	30	0.9861
0.5876	40	.5544	.7438	.8323	.9203	.6661	.8235	1.5013	.1765	20	0.9832
0.5905	50	.5568	.7457	.8307	.9194	.6703	.8263	1.4919	.1737	10	0.9803
0.5934	34°00′	.5592	9.7476	.8290	9.9186	.6745	9.8290	1.4826	0.1710	56°00′	0.9774
0.5963	10	.5616	.7494	.8274	.9177	.6787	.8317	1.4733	.1683	50	0.9745
0.5992	20	.5640	.7513	.8258	.9169	.6830	.8344	1.4641	.1656	40	0.9716
0.6021	30	.5664	.7531	.8241	.9160	.6873	.8371	1.4550	.1629	30	0.9687
0.6050	40	.5688	.7550	.8225	.9151	.6916	.8398	1.4460	.1602	20	0.9657
0.6080	50	.5712	.7568	.8208	.9142	.6959	.8425	1.4370	.1575	10	0.9628
0.6109	35°00′	.5736	9.7586	.8192	9.9134	.7002	9.8452	1.4281	0.1548	55°00′	0.9599
0.6138	10	.5760	.7604	.8175	.9125	.7046	.8479	1.4193	.1521	50	0.9570
0.6167	20	.5783	.7622	.8158	.9116	.7089	.8506	1.4106	.1494	40	0.9541
0.6196	30	.5807	.7640	.8141	.9107	.7133	.8533	1.4019	.1467	30	0.9512
0.6225	40	.5831	.7657	.8124	.9098	.7177	.8559	1.3934	.1441	20	0.9483
0.6254	50	.5854	.7675	.8107	.9089	.7221	.8586	1.3848	.1414	10	0.9454
0.6283	36°00′	.5878	9.7692	.8090	9.9080	.7265	9.8613	1.3764	0.1387	54°00′	0.9425
		Nat.	Log.	Nat.	Log.	Nat.	Log.	Nat.	Log.	DEGREES.	RADIANS.
		COSINES.		SINES.		COTANGENTS.		TANGENTS.			

CIRCULAR (TRIGONOMETRIC) FUNCTIONS.

RADIANS.	DEGREES.	SINES. Nat.	SINES. Log.	COSINES. Nat.	COSINES. Log.	TANGENTS. Nat.	TANGENTS. Log.	COTANGENTS. Nat.	COTANGENTS. Log.		
0.6283	36°00′	.5878	9.7692	.8090	9.9080	.7265	9.8613	1.3764	0.1387	54°00′	0.9425
0.6312	10	.5901	.7710	.8073	.9070	.7310	.8639	1.3680	.1361	50	0.9396
0.6341	20	.5925	.7727	.8056	.9061	.7355	.8666	1.3597	.1334	40	0.9367
0.6370	30	.5948	.7744	.8039	.9052	.7400	.8692	1.3514	.1308	30	0.9338
0.6400	40	.5972	.7761	.8021	.9042	.7445	.8718	1.3432	.1282	20	0.9308
0.6429	50	.5995	.7778	.8004	.9033	.7490	.8745	1.3351	.1255	10	0.9279
0.6458	37°00′	.6018	9.7795	.7986	9.9023	.7536	9.8771	1.3270	0.1229	53°00′	0.9250
0.6487	10	.6041	.7811	.7969	.9014	.7581	.8797	1.3190	.1203	50	0.9221
0.6516	20	.6065	.7828	.7951	.9004	.7627	.8824	1.3111	.1176	40	0.9192
0.6545	30	.6088	.7844	.7934	.8995	.7673	.8850	1.3032	.1150	30	0.9163
0.6574	40	.6111	.7861	.7916	.8985	.7720	.8876	1.2954	.1124	20	0.9134
0.6603	50	.6134	.7877	.7898	.8975	.7766	.8902	1.2876	.1098	10	0.9105
0.6632	38°00′	.6157	9.7893	.7880	9.8965	.7813	9.8928	1.2799	0.1072	52°00′	0.9076
0.6661	10	.6180	.7910	.7862	.8955	.7860	.8954	1.2723	.1046	50	0.9047
0.6690	20	.6202	.7926	.7844	.8945	.7907	.8980	1.2647	.1020	40	0.9018
0.6720	30	.6225	.7941	.7826	.8935	.7954	.9006	1.2572	.0994	30	0.8988
0.6749	40	.6248	.7957	.7808	.8925	.8002	.9032	1.2497	.0968	20	0.8959
0.6778	50	.6271	.7973	.7790	.8915	.8050	.9058	1.2423	.0942	10	0.8930
0.6807	39°00′	.6293	9.7989	.7771	9.8905	.8098	9.9084	1.2349	0.0916	51°00′	0.8901
0.6836	10	.6316	.8004	.7753	.8895	.8146	.9110	1.2276	.0890	50	0.8872
0.6865	20	.6338	.8020	.7735	.8884	.8195	.9135	1.2203	.0865	40	0.8843
0.6894	30	.6361	.8035	.7716	.8874	.8243	.9161	1.2131	.0839	30	0.8814
0.6923	40	.6383	.8050	.7698	.8864	.8292	.9187	1.2059	.0813	20	0.8785
0.6952	50	.6406	.8066	.7679	.8853	.8342	.9212	1.1988	.0788	10	0.8756
0.6981	40°00′	.6428	9.8081	.7660	9.8843	.8391	9.9238	1.1918	0.0762	50°00′	0.8727
0.7010	10	.6450	.8096	.7642	.8832	.8441	.9264	1.1847	.0736	50	0.8698
0.7039	20	.6472	.8111	.7623	.8821	.8491	.9289	1.1778	.0711	40	0.8668
0.7069	30	.6494	.8125	.7604	.8810	.8541	.9315	1.1708	.0685	30	0.8639
0.7098	40	.6517	.8140	.7585	.8800	.8591	.9341	1.1640	.0659	20	0.8610
0.7127	50	.6539	.8155	.7566	.8789	.8642	.9366	1.1571	.0634	10	0.8581
0.7156	41°00′	.6561	9.8169	.7547	9.8778	.8693	9.9392	1.1504	0.0608	49°00′	0.8552
0.7185	10	.6583	.8184	.7528	.8767	.8744	.9417	1.1436	.0583	50	0.8523
0.7214	20	.6604	.8198	.7509	.8756	.8796	.9443	1.1369	.0557	40	0.8494
0.7243	30	.6626	.8213	.7490	.8745	.8847	.9468	1.1303	.0532	30	0.8465
0.7272	40	.6648	.8227	.7470	.8733	.8899	.9494	1.1237	.0506	20	0.8436
0.7301	50	.6670	.8241	.7451	.8722	.8952	.9519	1.1171	.0481	10	0.8407
0.7330	42°00′	.6691	9.8255	.7431	9.8711	.9004	9.9544	1.1106	0.0456	48°00′	0.8378
0.7359	10	.6713	.8269	.7412	.8699	.9057	.9570	1.1041	.0430	50	0.8348
0.7389	20	.6734	.8283	.7392	.8688	.9110	.9595	1.0977	.0405	40	0.8319
0.7418	30	.6756	.8297	.7373	.8676	.9163	.9621	1.0913	.0379	30	0.8290
0.7447	40	.6777	.8311	.7353	.8665	.9217	.9646	1.0850	.0354	20	0.8261
0.7476	50	.6799	.8324	.7333	.8653	.9271	.9671	1.0786	.0329	10	0.8232
0.7505	43°00′	.6820	9.8338	.7314	9.8641	.9325	9.9697	1.0724	0.0303	47°00′	0.8203
0.7534	10	.6841	.8351	.7294	.8629	.9380	.9722	1.0661	.0278	50	0.8174
0.7563	20	.6862	.8365	.7274	.8618	.9435	.9747	1.0599	.0253	40	0.8145
0.7592	30	.6884	.8378	.7254	.8606	.9490	.9772	1.0538	.0228	30	0.8116
0.7621	40	.6905	.8391	.7234	.8594	.9545	.9798	1.0477	.0202	20	0.8087
0.7650	50	.6926	.8405	.7214	.8582	.9601	.9823	1.0416	.0177	10	0.8058
0.7679	44°00′	.6947	9.8418	.7193	9.8569	.9657	9.9848	1.0355	0.0152	46°00′	0.8029
0.7709	10	.6967	.8431	.7173	.8557	.9713	.9874	1.0295	.0126	50	0.7999
0.7738	20	.6988	.8444	.7153	.8545	.9770	.9899	1.0235	.0101	40	0.7970
0.7767	30	.7009	.8457	.7133	.8532	.9827	.9924	1.0176	.0076	30	0.7941
0.7796	40	.7030	.8469	.7112	.8520	.9884	.9949	1.0117	.0051	20	0.7912
0.7825	50	.7050	.8482	.7092	.8507	.9942	.9975	1.0058	.0025	10	0.7883
0.7854	45°00′	.7071	9.8495	.7071	9.8495	1.0000	0.0000	1.0000	0.0000	45°00′	0.7854
		Nat.	Log.	Nat	Log.	Nat.	Log.	Nat.	Log.	DEGREES.	RADIANS.
		COSINES.		SINES.		COTANGENTS.		TANGENTS.			

CIRCULAR (TRIGONOMETRIC) FUNCTIONS.*

RADIANS.	SINES.		COSINES.		TANGENTS.		COTANGENTS.		DEGREES.
	Nat.	Log.	Nat.	Log.	Nat.	Log.	Nat.	Log.	
0.00	0.00000	— ∞	1.00000	0.00000	— ∞	— ∞	.∞	∞	00°00′
.01	.01000	7.99999	0.99995	9.99998	0.01000	8.00001	99.997	1.99999	00 34
.02	.02000	8.30100	.99980	.99991	.02000	.30109	49.993	.69891	01 09
.03	.03000	.47706	.99955	.99980	.03001	.47725	33.323	.52275	01 43
.04	.03999	.60194	.99920	.99965	.04002	.60229	24.987	.39771	02 18
0.05	0.04998	8.69879	0.99875	9.99946	0.05004	8.69933	19.983	1.30067	02°52′
.06	.05996	.77789	.99820	.99922	.06007	.77867	16.647	.22133	03 26
.07	.06994	.84474	.99755	.99894	.07011	.84581	14.262	.15419	04 01
.08	.07991	.90263	.99680	.99861	.08017	.90402	12.473	.09598	04 35
.09	.08988	.95366	.99595	.99824	.09024	.95542	11.081	.04458	05 09
0.10	0.09983	8.99928	0.99500	9.99782	0.10033	9.00145	9.9666	0.99855	05°44′
.11	.10978	9.04052	.99396	.99737	.11045	.04315	9.0542	.95685	06 18
.12	.11971	.07814	.99281	.99687	.12058	.08127	8.2933	.91873	06 53
.13	.12963	.11272	.99156	.99632	.13074	.11640	7.6489	.88360	07 27
.14	.13954	.14471	.99022	.99573	.14092	.14898	7.0961	.85102	08 01
0.15	0.14944	9.17446	0.98877	9.99510	0.15114	9.17937	6.6166	0.82063	08°36′
.16	.15932	.20227	.98723	.99442	.16138	.20785	6.1966	.79215	09 10
.17	.16918	.22836	.98558	.99369	.17166	.23466	5.8256	.76534	09 44
.18	.17903	.25292	.98384	.99293	.18197	.26000	5.4954	.74000	10 19
.19	.18886	.27614	.98200	.99211	.19232	.28402	5.1997	.71598	10 53
0.20	0.19867	9.29813	0.98007	9.99126	0.20271	9.30688	4.9332	0.69312	11°28′
.21	.20846	.31902	.97803	.99035	.21314	.32867	4.6917	.67133	12 02
.22	.21823	.33891	.97590	.98940	.22362	.34951	4.4719	.65049	12 36
.23	.22798	.35789	.97367	.98841	.23414	.36948	4.2709	.63052	13 11
.24	.23770	.37603	.97134	.98737	.24472	.38866	4.0864	.61134	13 45
0.25	0.24740	9.39341	0.96891	9.98628	0.25534	9.40712	3.9163	0.59288	14°19′
.26	.25708	.41007	.96639	.98515	.26602	.42491	3.7592	.57509	14 54
.27	.26673	.42607	.96377	.98397	.27676	.44210	3.6133	.55790	15 28
.28	.27636	.44147	.96106	.98275	.28755	.45872	3.4776	.54128	16 03
.29	.28595	.45629	.95824	.98148	.29841	.47482	3.3511	.52518	16 37
0.30	0.29552	9.47059	0.95534	9.98016	0.30934	9.49043	3.2327	0.50957	17°11′
.31	.30506	.48438	.95233	.97879	.32033	.50559	3.1218	.49441	17 46
.32	.31457	.49771	.94924	.97737	.33139	.52034	3.0176	.47966	18 20
.33	.32404	.51060	.94604	.97591	.34252	.53469	2.9195	.46531	18 54
.34	.33349	.52308	.94275	.97440	.35374	.54868	2.8270	.45132	19 29
0.35	0.34290	9.53516	0.93937	9.97284	0.36503	9.56233	2.7395	0.43767	20°03′
.36	.35227	.54688	.93590	.97123	.37640	.57565	2.6567	.42435	20 38
.37	.36162	.55825	.93233	.96957	.38786	.58868	2.5782	.41132	21 12
.38	.37092	.56928	.92866	.96786	.39941	.60142	2.5037	.39858	21 46
.39	.38019	.58000	.92491	.96610	.41105	.61390	2.4328	.38610	22 21
0.40	0.38942	9.59042	0.92106	9.96429	0.42279	9.62613	2.3652	0.37387	22°55′
.41	.39861	.60055	.91712	.96243	.43463	.63812	2.3008	.36188	23 29
.42	.40776	.61041	.91309	.96051	.44657	.64989	2.2393	.35011	24 04
.43	.41687	.62000	.90897	.95855	.45862	.66145	2.1804	.33855	24 38
.44	.42594	.62935	.90475	.95653	.47078	.67282	2.1241	.32718	25 13
0.45	0.43497	9.63845	0.90045	9.95446	0.48306	9.68400	2.0702	0.31600	25°47′
.46	.44395	.64733	.89605	.95233	.49545	.69500	2.0184	.30500	26 21
.47	.45289	.65599	.89157	.95015	.50797	.70583	1.9686	.29417	26 56
.48	.46178	.66443	.88699	.94792	.52061	.71651	1.9208	.28349	27 30
.49	.47063	.67268	.88233	.94563	.53339	.72704	1.8748	.27296	28 04
0.50	0.47943	9.68072	0.87758	9.94329	0.54630	9.73743	1.8305	0.26257	28°39′

* Arranged and computed by C. E. Van Orstrand.

CIRCULAR (TRIGONOMETRIC) FUNCTIONS.

RADIANS.	SINES.		COSINES.		TANGENTS.		COTANGENTS.		DEGREES.
	Nat.	Log.	Nat.	Log.	Nat.	Log.	Nat.	Log.	
0.50	0.47943	9.68072	0.87758	9.94329	0.54630	9.73743	1.8305	0.26257	28°39′
.51	.48818	.68858	.87274	.94089	.55936	.74769	.7878	.25231	29 13
.52	.49688	.69625	.86782	.93843	.57256	.75782	.7465	.24218	29 48
.53	.50553	.70375	.86281	.93591	.58592	.76784	.7067	.23216	30 22
.54	.51414	.71108	.85771	.93334	.59943	.77774	.6683	.22226	30 56
0.55	0.52269	9.71824	0.85252	9.93071	0.61311	9.78754	1.6310	0.21246	31°31′
.56	.53119	.72525	.84726	.92801	.62695	.79723	.5950	.20277	32 05
.57	.53963	.73210	.84190	.92526	.64097	.80684	.5601	.19316	32 40
.58	.54802	.73880	.83646	.92245	.65517	.81635	.5263	.18365	33 14
.59	.55636	.74536	.83094	.91957	.66956	.82579	.4935	.17421	33 48
0.60	0.56464	9.75177	0.82534	9.91663	0.68414	9.83514	1.4617	0.16486	34°23′
.61	.57287	.75805	.81965	.91363	.69892	.84443	.4308	.15557	34 57
.62	.58104	.76420	.81388	.91056	.71391	.85364	.4007	.14636	35 31
.63	.58914	.77022	.80803	.90743	.72911	.86280	.3715	.13720	36 06
.64	.59720	.77612	.80210	.90423	.74454	.87189	.3431	.12811	36 40
0.65	0.60519	9.78189	0.79608	9.90096	0.76020	9.88093	1.3154	0.11907	37°15′
.66	.61312	.78754	.78999	.89762	.77610	.88992	.2885	.11008	37 49
.67	.62099	.79308	.78382	.89422	.79225	.89886	.2622	.10114	38 23
.68	.62879	.79851	.77757	.89074	.80866	.90777	.2366	.09223	38 58
.69	.63654	.80382	.77125	.88719	.82534	.91663	.2116	.08337	39 32
0.70	0.64422	9.80903	0.76484	9.88357	0.84229	9.92546	1.1872	0.07454	40°06′
.71	.65183	.81414	.75836	.87988	.85953	.93426	.1634	.06574	40 41
.72	.65938	.81914	.75181	.87611	.87707	.94303	.1402	.05697	41 15
.73	.66687	.82404	.74517	.87226	.89492	.95178	.1174	.04822	41 50
.74	.67429	.82885	.73847	.86833	.91309	.96051	.0952	.03949	42 24
0.75	0.68164	9.83355	0.73169	9.86433	0.93160	9.96923	1.0734	0.03077	42°58′
.76	.68892	.83817	.72484	.86024	.95045	.97793	.0521	.02207	43 33
.77	.69614	.84269	.71791	.85607	.96967	.98662	.0313	.01338	44 07
.78	.70328	.84713	.71091	.85182	.98926	9.99531	1.0109	.00469	44 41
.79	.71035	.85147	.70385	.84748	1.0092	0.00400	0.99084	9.99600	45 16
0.80	0.71736	9.85573	0.69671	9.84305	1.0296	0.01268	0.97121	9.98732	45°50′
.81	.72429	.85991	.68950	.83853	.0505	.02138	.95197	.97862	46 28
.82	.73115	.86400	.68222	.83393	.0717	.03008	.93309	.96992	46 59
.83	.73793	.86802	.67488	.82922	.0934	.03879	.91455	.96121	47 33
.84	.74464	.87195	.66746	.82443	.1156	.04752	.89635	.95248	48 08
0.85	0.75128	9.87580	0.65998	9.81953	1.1383	0.05627	0.87848	9.94373	48°42′
.86	.75784	.87958	.65244	.81454	.1616	.06504	.86091	.93496	49 16
.87	.76433	.88328	.64483	.80944	.1853	.07384	.84365	.92616	49 51
.88	.77074	.88691	.63715	.80424	.2097	.08266	.82668	.91734	50 25
.89	.77707	.89046	.62941	.79894	.2346	.09153	.80998	.90847	51 00
0.90	0.78333	9.89394	0.62161	9.79352	1.2602	0.10043	0.79355	9.89957	51°34′
.91	.78950	.89735	.61375	.78799	.2864	.10937	.77738	.89063	52 08
.92	.79560	.90070	.60582	.78234	.3133	.11835	.76146	.88165	52 43
.93	.80162	.90397	.59783	.77658	.3409	.12739	.74578	.87261	53 17
.94	.80756	.90717	.58979	.77070	.3692	.13648	.73034	.86352	53 51
0.95	0.81342	9.91031	0.58168	9.76469	1.3984	0.14563	0.71511	9.85437	54°26′
.96	.81919	.91339	.57352	.75855	.4284	.15484	.70010	.84516	55 00
.97	.82489	.91639	.56530	.75228	.4592	.16412	.68531	.83588	55 35
.98	.83050	.91934	.55702	.74587	.4910	.17347	.67071	.82653	56 09
.99	.83603	.92222	.54869	.73933	.5237	.18289	.65631	.81711	56 43
1.00	0.84147	9.92504	0.54030	9.73264	1.5574	0.19240	0.64209	9.80760	57°18′

CIRCULAR (TRIGONOMETRIC) FUNCTIONS.

SINES.	COSINES.		TANGENTS.		COTANGENTS.		DEGREES.
Log.	Nat.	Log.	Nat.	Log.	Nat.	Log.	
9.92504	0.54030	9.73264	1.5574	0.19240	0.64209	9.80760	57°18′
.92780	.53186	.72580	.5922	.20200	.62806	.79800	57 52
.93049	.52337	.71881	.6281	.21169	.61420	.78831	58 27
.93313	.51482	.71165	.6652	.22148	.60051	.77852	59 01
.93571	.50622	.70434	.7036	.23137	.58699	.76863	59 35
9.93823	0.49757	9.69686	1.7433	0.24138	0.57362	9.75862	60°10′
.94069	.48887	.68920	.7844	.25150	.56040	.74850	60 44
.94310	.48012	.68135	.8270	.26175	.54734	.73825	61 18
.94545	.47133	.67332	.8712	.27212	.53441	.72788	61 53
.94774	.46249	.66510	.9171	.28264	.52162	.71736	62 27
9.94998	0.45360	9.65667	1.9648	0.29331	0.50897	9.70669	63°02′
.95216	.44466	.64803	2.0143	.30413	.49644	.69587	63 36
.95429	.43568	.63917	.0660	.31512	.48404	.68488	64 10
.95637	.42666	.63008	.1197	.32628	.47175	.67372	64 45
.95839	.41759	.62075	.1759	.33763	.45959	.66237	65 19
9.96036	0.40849	9.61118	2.2345	0.34918	0.44753	9.65082	65°53′
.96228	.39934	.60134	.2958	.36093	.43558	.63907	66 28
.96414	.39015	.59123	.3600	.37291	.42373	.62709	67 02
.96596	.38092	.58084	.4273	.38512	.41199	.61488	67 37
.96772	.37166	.57015	.4979	.39757	.40034	.60243	68 11
9.96943	0.36236	9.55914	2.5722	0.41030	0.38878	9.58970	68°45′
.97110	.35302	.54780	.6503	.42330	.37731	.57670	69 20
.97271	.34365	.53611	.7328	.43660	.36593	.56340	69 54
.97428	.33424	.52406	.8198	.45022	.35463	.54978	70 28
.97579	.32480	.51161	.9119	.46418	.34341	.53582	71 03
9.97726	0.31532	9.49875	3.0096	0.47850	0.33227	9.52150	71°37′
.97868	.30582	.48546	.1133	.49322	.32121	.50678	72 12
.98005	.29628	.47170	.2236	.50835	.31021	.49165	72 46
.98137	.28672	.45745	.3413	.52392	.29928	.47608	73 20
.98265	.27712	.44267	.4672	.53998	.28842	.46002	73 55
9.98388	0.26750	9.42732	3.6021	0.55656	0.27762	9.44344	74°29′
.98506	.25785	.41137	.7471	.57369	.26687	.42631	75 03
.98620	.24818	.39476	.9033	.59144	.25619	.40856	75 38
.98729	.23848	.37744	4.0723	.60984	.24556	.39016	76 12
.98833	.22875	.35937	.2556	.62896	.23498	.37104	76 47
9.98933	0.21901	9.34046	4.4552	0.64887	0.22446	9.35113	77°21′
.99028	.20924	.32064	.6734	.66964	.21398	.33036	77 55
.99119	.19945	.29983	.9131	.69135	.20354	.30865	78 30
.99205	.18964	.27793	5.1774	.71411	.19315	.28589	79 04
.99286	.17981	.25482	.4707	.73804	.18279	.26196	79 38
9.99363	0.16997	9.23036	5.7979	0.76327	0.17248	9.23673	80°13′
.99436	.16010	.20440	6.1654	.78996	.16220	.21004	80 47
.99504	.15023	.17674	6.5811	.81830	.15195	.18170	81 22
.99568	.14033	.14716	7.0555	.84853	.14173	.15147	81 56
.99627	.13042	.11536	7.6018	.88092	.13155	.11908	82 30
9.99682	0.12050	9.08100	8.2381	0.91583	0.12139	9.08417	83°05′
.99733	.11057	.04364	8.9886	.95369	.11125	.04631	83 39
.99779	.10063	.00271	9.8874	.99508	.10114	.00492	84 13
.99821	.09067	8.95747	10.983	1.04074	.09105	8.95926	84 48
.99858	.08071	.90692	12.350	.09166	.08097	.90834	85 22
9.99891	0.07074	8.84965	14.101	1.14926	0.07091	8.85074	85°57′

TABLE 12 (*continued*). — Circular (Trigonometric) Functions.

RADIANS.	SINES.		COSINES.		TANGENTS.		COTANGENTS.		
	Nat.	Log.	Nat.	Log.	Nat.	Log.	Nat.	Log.	
1.50	0.99749	9.99891	0.07074	8.84965	14.101	1.14926	0.07091	8.85074	85
.51	.99815	.99920	.06076	.78361	16.428	.21559	.06087	.78441	86
.52	.99871	.99944	.05077	.70565	19.670	.29379	.05084	.70621	87
.53	.99917	.99964	.04079	.61050	24.498	.38914	.04082	.61086	87
.54	.99953	.99979	.03079	.48843	32.461	.51136	.03081	.48864	88
1.55	0.99978	9.99991	0.02079	8.31796	48.078	1.68195	0.02080	8.31805	88
.56	0.99994	9.99997	.01080	8.03327	92.621	1.96671	.01080	8.03330	89
.57	1.00000	0.00000	.00080	6.90109	1255.8	3.09891	.00080	6.90109	89
.58	0.99996	9.99998	−.00920	7.96396n	108.65	2.03603	−.00920	7.96397n	90
.59	0.99982	9.99992	−.01920	8.28336n	52.067	1.71656	−.01921	8.28344n	91
1.60	0.99957	9.99981	−0.02920	8.46538n	34.233	1.53444	−0.02921	8.46556n	91

$90° = 1.570\,7963$ radians.

TABLE 12a. — Factorials.

Logarithms of the products $1.2.3. \ldots\ldots n$, n from 1 to 100.

See Table 30 for log. $\Gamma(n+1)$, values of n between 1 and 2.

n.	log.(*n!*)	*n.*	log.(*n!*)	*n.*	log.(*n!*)	*n.*	log.(*n!*)
1	0.000000	**26**	26.605619	**51**	66.190645	**76**	111.275425
2	0.301029	27	28.036982	52	67.906648	77	113.161916
3	0.778151	28	29.484140	53	69.630924	78	115.054010
4	1.380211	29	30.946538	54	71.363318	79	116.951637
5	2.079181	30	32.423660	55	73.103680	80	118.854727
6	2.857332	**31**	33.915021	**56**	74.851868	**81**	120.763212
7	3.702430	32	35.420171	57	76.607743	82	122.677026
8	4.605520	33	36.938685	58	78.371171	83	124.596104
9	5.559763	34	38.470164	59	80.142023	84	126.520383
10	6.559763	35	40.014232	60	81.920174	85	128.449802
11	7.601155	**36**	41.570535	**61**	83.705504	**86**	130.384301
12	8.680336	37	43.138736	62	85.497896	87	132.323820
13	9.794280	38	44.718520	63	87.297236	88	134.268303
14	10.940408	39	46.309585	64	89.103416	89	136.217693
15	12.116499	40	47.911645	65	90.916330	90	138.171935
16	13.320619	**41**	49.524428	**66**	92.735874	**91**	140.130977
17	14.551068	42	51.147678	67	94.561948	92	142.094765
18	15.806341	43	52.781146	68	96.394457	93	144.063247
19	17.085094	44	54.424599	69	98.233306	94	146.036375
20	18.386124	45	56.077811	70	100.078405	95	148.014099
21	19.708343	**46**	57.740569	**71**	101.929663	**96**	149.996370
22	21.050766	47	59.412667	72	103.786995	97	151.983142
23	22.412494	48	61.093908	73	105.650318	98	153.974368
24	23.792705	49	62.784104	74	107.519550	99	155.970003
25	25.190645	50	64.483074	75	109.394611	100	157.970003

HYPERBOLIC FUNCTIONS.*

Hyperbolic sines. Values of $\frac{e^x - e^{-x}}{2}$.

x	0	1	2	3	4	5	6	7	8	9
0.0	0.0000	0.0100	0.0200	0.0300	0.0400	0.0500	0.0600	0.0701	0.0801	0.0901
0.1	.1002	.1102	.1203	.1304	.1405	.1506	.1607	.1708	.1810	.1911
0.2	.2013	.2115	.2218	.2320	.2423	.2526	.2629	.2733	.2837	.2941
0.3	.3045	.3150	.3255	.3360	.3466	.3572	.3678	.3785	.3892	.4000
0.4	.4108	.4216	.4325	.4434	.4543	.4653	.4764	.4875	.4986	.5098
0.5	0.5211	0.5324	0.5438	0.5552	0.5666	0.5782	0.5897	0.6014	0.6131	0.6248
0.6	.6367	.6485	.6605	.6725	.6846	.6967	.7090	.7213	.7336	.7461
0.7	.7586	.7712	.7838	.7966	.8094	.8223	.8353	.8484	.8615	.8748
0.8	.8881	.9015	.9150	.9286	.9423	.9561	.9700	.9840	.9981	.0122
0.9	1.0265	1.0409	1.0554	1.0700	1.0847	1.0995	1.1144	1.1294	1.1446	1.1598
1.0	1.1752	1.1907	1.2063	1.2220	1.2379	1.2539	1.2700	1.2862	1.3025	1.3190
1.1	.3356	.3524	.3693	.3863	.4035	.4208	.4382	.4558	.4735	.4914
1.2	.5095	.5276	.5460	.5645	.5831	.6019	.6209	.6400	.6593	.6788
1.3	.6984	.7182	.7381	.7583	.7786	.7991	.8198	.8406	.8617	.8829
1.4	.9043	.9259	.9477	.9697	.9919	2.0143	2.0369	2.0597	2.0827	2.1059
1.5	2.1293	2.1529	2.1768	2.2008	2.2251	2.2496	2.2743	2.2993	2.3245	2.3499
1.6	.3756	.4015	.4276	.4540	.4806	.5075	.5346	.5620	.5896	.6175
1.7	.6456	.6740	.7027	.7317	.7609	.7904	.8202	.8503	.8806	.9112
1.8	.9422	.9734	3.0049	3.0367	3.0689	3.1013	3.1340	3.1671	3.2005	3.2341
1.9	3.2682	3.3025	.3372	.3722	.4075	.4432	.4792	.5156	.5523	.5894
2.0	3.6269	3.6647	3.7028	3.7414	3.7803	3.8196	3.8593	3.8993	3.9398	3.9806
2.1	4.0219	4.0635	4.1056	4.1480	4.1909	4.2342	4.2779	4.3221	4.3666	4.4117
2.2	4.4571	4.5030	4.5494	4.5962	4.6434	4.6912	4.7394	4.7880	4.8372	4.8868
2.3	4.9370	4.9876	5.0387	5.0903	5.1425	5.1951	5.2483	5.3020	5.3562	5.4109
2.4	5.4662	5.5221	5.5785	5.6354	5.6929	5.7510	5.8097	5.8689	5.9288	5.9892
2.5	6.0502	6.1118	6.1741	6.2369	6.3004	6.3645	6.4293	6.4946	6.5607	6.6274
2.6	6.6947	6.7628	6.8315	6.9009	6.9709	7.0417	7.1132	7.1854	7.2583	7.3319
2.7	7.4063	7.4814	7.5572	7.6338	7.7112	7.7894	7.8683	7.9480	8.0285	8.1098
2.8	8.1919	8.2749	8.3586	8.4432	8.5287	8.6150	8.7021	8.7902	8.8791	8.9689
2.9	9.0596	9.1512	9.2437	9.3371	9.4315	9.5268	9.6231	9.7203	9.8185	9.9177
3.0	10.018	10.119	10.221	10.324	11.429	11.534	11.640	11.748	11.856	11.966
3.1	11.076	11.188	11.301	11.415	11.530	12.647	12.764	12.883	12.003	12.124
3.2	12.246	12.369	12.494	12.620	12.747	12.876	13.006	13.137	13.269	13.403
3.3	13.538	13.674	13.812	13.951	14.092	14.234	14.377	14.522	14.668	14.816
3.4	14.965	15.116	15.268	15.422	15.577	15.734	15.893	16.053	16.214	16.378
3.5	16.543	16.709	16.877	17.047	17.219	17.392	17.567	17.744	17.923	18.103
3.6	18.285	18.470	18.655	18.843	19.033	19.224	19.418	19.613	19.811	20.010
3.7	20.211	20.415	20.620	20.828	21.037	21.249	21.463	21.679	21.897	22.117
3.8	22.339	22.564	22.791	23.020	23.252	23.486	23.722	23.961	24.202	24.445
3.9	24.691	24.939	25.190	25.444	25.700	25.958	26.219	26.483	26.749	27.018
4.0	27.290	27.564	27.842	28.122	28.404	28.690	28.979	29.270	29.564	29.862
4.1	30.162	30.465	30.772	31.081	31.393	31.709	32.028	32.350	32.675	33.004
4.2	33.336	33.671	34.009	34.351	34.697	35.046	35.398	35.754	36.113	36.476
4.3	36.843	37.214	37.588	37.966	38.347	38.733	39.122	39.515	39.913	40.314
4.4	40.719	41.129	41.542	41.960	42.382	42.808	43.238	43.673	44.112	44.555
4.5	45.003	45.455	45.912	46.374	46.840	47.311	47.787	48.267	48.752	49.242
4.6	49.737	50.237	50.742	51.252	51.767	52.288	52.813	53.344	53.880	54.422
4.7	54.969	55.522	56.080	56.643	57.213	57.788	58.369	58.955	59.548	60.147
4.8	60.751	61.362	61.979	62.601	63.231	63.866	64.508	65.157	65.812	66.473
4.9	67.141	67.816	68.498	69.186	69.882	70.584	71.293	72.010	72.734	73.465

*Tables 38–41 are quoted from "Des Ingenieurs Taschenbuch," herausgegeben vom Akademischen Verein (Hütte).

TABLE 14.

HYPERBOLIC FUNCTIONS.

Common logarithms + 10 of the hyperbolic sines.

x	0	1	2	3	4	5	6	7	8	9
0.0	— ∞	8.0000	3011	4772	6022	6992	7784	8455	9036	9548
0.1	9.0007	0423	0802	1152	1475	1777	2060	2325	2576	2814
0.2	3039	3254	3459	3656	3844	4025	4199	4366	4528	4685
0.3	4836	4983	5125	5264	5398	5529	5656	5781	5902	6020
0.4	9.6136	6249	6359	6468	6574	6678	6780	6880	6978	7074
0.5	9.7169	7262	7354	7444	7533	7620	7707	7791	7875	7958
0.6	8039	8119	8199	8277	8354	8431	8506	8581	8655	8728
0.7	8800	8872	8942	9012	9082	9150	9218	9286	9353	9419
0.8	9485	9550	9614	9678	9742	9805	9868	9930	9992	0053
0.9	10.0114	0174	0234	0294	0353	0412	0470	0529	0586	0644
1.0	10.0701	0758	0815	0871	0927	0982	1038	1093	1148	1203
1.1	1257	1311	1365	1419	1472	1525	1578	1631	1684	1736
1.2	1788	1840	1892	1944	1995	2046	2098	2148	2199	2250
1.3	2300	2351	2401	2451	2501	2551	2600	2650	2699	2748
1.4	2797	2846	2895	2944	2993	3041	3090	3138	3186	3234
1.5	10.3282	3330	3378	3426	3474	3521	3569	3616	3663	3711
1.6	3758	3805	3852	3899	3946	3992	4039	4086	4132	4179
1.7	4225	4272	4318	4364	4411	4457	4503	4549	4595	4641
1.8	4687	4733	4778	4824	4870	4915	4961	5007	5052	5098
1.9	5143	5188	5234	5279	5324	5370	5415	5460	5505	5550
2.0	10.5595	5640	5685	5730	5775	5820	5865	5910	5955	5999
2.1	6044	6089	6134	6178	6223	6268	6312	6357	6401	6446
2.2	6491	6535	6580	6624	6668	6713	6757	6802	6846	6890
2.3	6935	6979	7023	7067	7112	7156	7200	7244	7289	7333
2.4	7377	7421	7465	7509	7553	7597	7642	7686	7730	7774
2.5	10.7818	7862	7906	7950	7994	8038	8082	8126	8169	8213
2.6	8257	8301	8345	8389	8433	8477	8521	8564	8608	8652
2.7	8696	8740	8784	8827	8871	8915	8959	9003	9046	9090
2.8	9134	9178	9221	9265	9309	9353	9396	9440	9484	9527
2.9	9571	9615	9658	9702	9746	9789	9833	9877	9920	9964
3.0	11.0008	0051	0095	0139	0182	0226	0270	0313	0357	0400
3.1	0444	0488	0531	0575	0618	0662	0706	0749	0793	0836
3.2	0880	0923	0967	1011	1054	1098	1141	1185	1228	1272
3.3	1316	1359	1403	1446	1490	1533	1577	1620	1664	1707
3.4	1751	1794	1838	1881	1925	1968	2012	2056	2099	2143
3.5	11.2186	2230	2273	2317	2360	2404	2447	2491	2534	2578
3.6	2621	2665	2708	2752	2795	2839	2882	2925	2969	3012
3.7	3056	3099	3143	3186	3230	3273	3317	3360	3404	3447
3.8	3491	3534	3578	3621	3665	3708	3752	3795	3838	3882
3.9	3925	3969	4012	4056	4099	4143	4186	4230	4273	4317
4.0	11.4360	4403	4447	4490	4534	4577	4621	4664	4708	4751
4.1	4795	4838	4881	4925	4968	5012	5055	5099	5142	5186
4.2	5229	5273	5316	5359	5403	5446	5490	5533	5577	5620
4.3	5664	5707	5750	5794	5837	5881	5924	5968	6011	6055
4.4	6098	6141	6185	6228	6272	6315	6359	6402	6446	6489
4.5	11.6532	6576	6619	6663	6706	6750	6793	6836	6880	6923
4.6	6967	7010	7054	7097	7141	7184	7227	7271	7314	7358
4.7	7401	7445	7488	7531	7575	7618	7662	7705	7749	7792
4.8	7836	7879	7922	7966	8009	8053	8096	8140	8183	8226
4.9	8270	8313	8357	8400	8444	8487	8530	8574	8617	8661

HYPERBOLIC FUNCTIONS.

Hyperbolic cosines. Values of $\frac{e^x + e^{-x}}{2}$.

x	0	1	2	3	4	5	6	7	8	9
0.0	1.0000	1.0001	1.0002	1.0005	1.0008	1.0013	1.0018	1.0025	1.0032	1.0041
0.1	.0050	.0061	.0072	.0085	.0098	.0113	.0128	.0145	.0162	.0181
0.2	.0201	.0221	.0243	.0266	.0289	.0314	.0340	.0367	.0395	.0423
0.3	.0453	.0484	.0516	.0549	.0584	.0619	.0655	.0692	.0731	.0770
0.4	.0811	.0852	.0895	.0939	.0984	.1030	.1077	.1125	.1174	.1225
0.5	1.1276	1.1329	1.1383	1.1438	1.1494	1.1551	1.1609	1.1669	1.1730	1.1792
0.6	.1855	.1919	.1984	.2051	.2119	.2188	.2258	.2330	.2402	.2476
0.7	.2552	.2628	.2706	.2785	.2865	.2947	.3030	.3114	.3199	.3286
0.8	.3374	.3464	.3555	.3647	.3740	.3835	.3932	.4029	.4128	.4229
0.9	.4331	4434	.4539	.4645	.4753	.4862	.4973	.5085	.5199	.5314
1.0	1.5431	1.5549	1.5669	1.5790	1.5913	1.6038	.6164	1.6292	1.6421	1.6552
1.1	.6685	.6820	.6956	.7093	.7233	.7374	.7517	.7662	.7808	.7956
1.2	.8107	.8258	.8412	.8568	.8725	.8884	.9045	.9208	.9373	.9540
1.3	.9709	.9880	2.0053	2.0228	2.0404	2.0583	2.0764	2.0947	2.1132	2.1320
1.4	2.1509	.1700	.1894	.2090	.2288	.2488	.2691	.2896	.3103	.3312
1.5	2.3524	2.3738	2.3955	2.4174	2.4395	2.4619	2.4845	2.5073	2.5305	2.5538
1.6	.5775	.6013	.6255	.6499	.6746	.6995	.7247	.7502	.7760	.8020
1.7	.8283	.8549	.8818	.9090	.9364	.9642	.9922	3.0206	3.0492	3.0782
1.8	3.1075	3.1371	3.1669	3.1972	3.2277	3.2585	3.2897	.3212	.3530	.3852
1.9	.4177	.4506	.4838	.5173	.5512	.5855	.6201	.6551	.6904	.7261
2.0	3.7622	3.7987	3.8355	3.8727	3.9103	3.9483	3.9867	4.0255	4.0647	4.1043
2.1	4.1443	4.1847	4.2256	4.2668	4.3085	4.3507	4.3932	4.4362	4.4797	4.5236
2.2	4.5679	4.6127	4.6580	4.7037	4.7499	4.7966	4.8437	4.8914	4.9395	4.9881
2.3	5.0372	5.0868	5.1370	5.1876	5.2388	5.2905	5.3427	5.3954	5.4487	5.5026
2.4	5.5569	5.6119	5.6674	5.7235	5.7801	5.8373	5.8951	5.9535	6.0125	6.0721
2.5	6.1323	6.1931	6.2545	6.3166	6.3793	6.4426	6.5066	6.5712	6.6365	6.7024
2.6	6.7690	6.8363	6.9043	6.9729	7.0423	7.1123	7.1831	7.2546	7.3268	7.3998
2.7	7.4735	7.5479	7.6231	7.6990	7.7758	7.8533	7.9316	8.0106	8.0905	8.1712
2.8	8.2527	8.3351	8.4182	8.5022	8.5871	8.6728	8.7594	8.8469	8.9352	9.0244
2.9	9.1146	9.2056	9.2976	9.3905	9.4844	9.5791	9.6749	9.7716	9.8693	9.9680
3.0	10.068	10.168	10.270	10.373	10.476	10.581	10.687	10.794	10.902	11.011
3.1	11.121	12.233	11.345	11.459	11.574	11.689	11.806	11.925	12.044	12.165
3.2	12.287	12.410	12.534	12.660	12.786	12.915	13.044	13.175	13.307	13.440
3.3	13.575	13.711	13.848	13.987	14.127	14.269	14.412	14.556	14.702	14.850
3.4	14.999	15.149	15.301	15.455	15.610	15.766	15.924	16.084	16.245	16.408
3.5	16.573	16.739	16.907	17.077	17.248	17.421	17.596	17.772	17.951	18.131
3.6	18.313	18.497	18.682	18.870	19.059	19.250	19.444	19.639	19.836	20.035
3.7	20.236	20.439	20.644	20.852	21.061	21.272	21.486	21.702	21.919	22.139
3.8	22.362	22.586	22.813	23.042	23.273	23.507	23.743	23.982	24.222	24.466
3.9	24.711	24.959	25.210	25.463	25.719	25.977	26.238	26.502	26.768	27.037
4.0	27.308	27.582	27.860	28.139	28.422	28.707	28.996	29.287	29.581	29.878
4.1	30.178	30.482	30.788	31.097	31.409	31.725	32.044	32.365	32.691	33.019
4.2	33.351	33.686	34.024	34.366	34.711	35.060	35.412	35.768	36.127	36.490
4.3	36.857	37.227	37.601	37.979	38.360	38.746	39.135	39.528	39.925	40.326
4.4	40.732	41.141	41.554	41.972	42.393	42.819	43.250	43.684	44.123	44.566
4.5	45.014	45.466	45.923	46.385	46.851	47.321	47.797	48.277	48.762	49.252
4.6	49.747	50.247	50.752	51.262	51.777	52.297	52.823	53.354	53.890	54.431
4.7	54.978	55.531	56.089	56.652	57.221	57.796	58.377	58.964	59.556	60.155
4.8	60.759	61.370	61.987	62.609	63.239	63.874	64.516	65.164	65.819	66.481
4.9	67.149	67.823	68.505	69.193	69.889	70.591	71.300	72.017	72.741	73.472

TABLE 16.

HYPERBOLIC FUNCTIONS.

Common logarithms of the hyperbolic cosines.

x	0	1	2	3	4	5	6	7	8	9
0.0	0.0000	0000	0001	0002	0003	0005	0008	0011	0014	0018
0.1	0022	0026	0031	0037	0042	0049	0055	0062	0070	0078
0.2	0086	0095	0104	0114	0124	0134	0145	0156	0168	0180
0.3	0193	0205	0219	0232	0246	0261	0276	0291	0306	0322
0.4	0339	0355	0372	0390	0407	0426	0444	0463	0482	0502
0.5	0.0522	0542	0562	0583	0605	0626	0648	0670	0693	0716
0.6	0739	0762	0786	0810	0835	0859	0884	0910	0935	0961
0.7	0987	1013	1040	1067	1094	1122	1149	1177	1206	1234
0.8	1263	1292	1321	1350	1380	1410	1440	1470	1501	1532
0.9	1563	1594	1625	1657	1689	1721	1753	1785	1818	1851
1.0	0.1884	1917	1950	1984	2018	2051	2086	2120	2154	2189
1.1	2223	2258	2293	2328	2364	2399	2435	2470	2506	2542
1.2	2578	2615	2651	2688	2724	2761	2798	2835	2872	2909
1.3	2947	2984	3022	3059	3097	3135	3173	3211	3249	3288
1.4	3326	3365	3403	3442	3481	3520	3559	3598	3637	3676
1.5	0.3715	3754	3794	3833	3873	3913	3952	3992	4032	4072
1.6	4112	4152	4192	4232	4273	4313	4353	4394	4434	4475
1.7	4515	4556	4597	4637	4678	4719	4760	4801	4842	4883
1.8	4924	4965	5006	5048	5089	5130	5172	5213	5254	5296
1.9	5337	5379	5421	5462	5504	5545	5587	5629	5671	5713
2.0	0.5754	5796	5838	5880	5922	5964	6006	6048	6090	6132
2.1	6175	6217	6259	6301	6343	6386	6428	6470	6512	6555
2.2	6597	6640	6682	6724	6767	6809	6852	6894	6937	6979
2.3	7022	7064	7107	7150	7192	7235	7278	7320	7363	7406
2.4	7448	7491	7534	7577	7619	7662	7705	7748	7791	7833
2.5	0.7876	7919	7962	8005	8048	8091	8134	8176	8219	8262
2.6	8305	8348	8391	8434	8477	8520	8563	8606	8649	8692
2.7	8735	8778	8821	8864	8907	8951	8994	9037	9080	9123
2.8	9166	9209	9252	9295	9338	9382	9425	9468	9511	9554
2.9	9597	9641	9684	9727	9770	9813	9856	9900	9943	9986
3.0	1.0029	0073	0116	0159	0202	0245	0289	0332	0375	0418
3.1	0462	0505	0548	0591	0635	0678	0721	0764	0808	0851
3.2	0894	0938	0981	1024	1067	1111	1154	1197	1241	1284
3.3	1327	1371	1414	1457	1501	1544	1587	1631	1674	1717
3.4	1761	1804	1847	1891	1934	1977	2021	2064	2107	2151
3.5	1.2194	2237	2281	2324	2367	2411	2454	2497	2541	2584
3.6	2628	2671	2714	2758	2801	2844	2888	2931	2974	3018
3.7	3061	3105	3148	3191	3235	3278	3322	3365	3408	3452
3.8	3495	3538	3582	3625	3669	3712	3755	3799	3842	3886
3.9	3929	3972	4016	4059	4103	4146	4189	4233	4278	4320
4.0	1.4363	4406	4450	4493	4537	4580	4623	4667	4710	4754
4.1	4797	4840	4884	4927	4971	5014	5057	5101	5144	5188
4.2	5231	5274	5318	5361	5405	5448	5492	5535	5578	5622
4.3	5665	5709	5752	5795	5839	5882	5926	5969	6012	6056
4.4	6099	6143	6186	6230	6273	6316	6360	6403	6447	6490
4.5	1.6533	6577	6620	6664	6707	6751	6794	6837	6881	6924
4.6	6968	7011	7055	7098	7141	7185	7228	7272	7315	7358
4.7	7402	7445	7489	7532	7576	7619	7662	7706	7749	7793
4.8	7836	7880	7923	7966	8010	8053	8097	8140	8184	8227
4.9	8270	8314	8357	8401	8444	8487	8531	8574	8618	8661

EXPONENTIAL FUNCTIONS.

Values of e^x and e^{-x} intermediate to those here given may be found by adding or subtracting the values of the hyperbolic cosine and sine given in Tables 15 and 13.

x	$\log_{10}(e^x)$	e^x	e^{-x}	x	$\log_{10}(e^x)$	e^x	e^{-x}
0.0	0.00000	1.0000	1.000000	5.0	2.17147	148.41	0.006738
.1	.04343	.1052	0.904837	.1	.21490	164.02	.006097
.2	.08686	.2214	.818731	.2	.25833	181.27	.005517
.3	.13029	.3499	.740818	.3	.30176	200.34	.004992
.4	.17372	.4918	.670320	.4	.34519	221.41	.004517
0.5	0.21715	1.6487	0.606531	5.5	2.38862	244.69	0.004087
.6	.26058	.8221	.548812	.6	.43205	270.43	.003698
.7	.30401	2.0138	.496585	.7	.47548	298.87	.003346
.8	.34744	.2255	.449329	.8	.51891	330.30	.003028
.9	.39087	.4596	.406570	.9	.56234	365.04	.002739
1.0	0.43429	2.7183	0.367879	6.0	2.60577	403.43	0.002479
.1	.47772	3.0042	.332871	.1	.64920	445.86	.002243
.2	.52115	.3201	.301194	.2	.69263	492.75	.002029
.3	.56458	.6693	.272532	.3	.73606	544.57	.001836
.4	.60801	4.0552	.246597	.4	.77948	601.85	.001662
1.5	0.65144	4.4817	0.223130	6.5	2.82291	665.14	0.001503
.6	.69487	.9530	.201897	.6	.86634	735.10	.001360
.7	.73830	5.4739	.182684	.7	.90977	812.41	.001231
.8	.78173	6.0496	.165299	.8	.95320	897.85	.001114
.9	.82516	6.6859	.149569	.9	.99663	992.27	.001008
2.0	0.86859	7.3891	0.135335	7.0	3.04006	1096.6	0.000912
.1	.91202	8.1662	.122456	.1	.08349	1212.0	.000825
.2	.95545	9.0250	.110803	.2	.12692	1339.4	.000747
.3	.99888	9.9742	.100259	.3	.17035	1480.3	.000676
.4	1.04231	11.023	.090718	.4	.21378	1636.0	.000611
2.5	1.08574	12.182	0.082085	7.5	3.25721	1808.0	0.000553
.6	.12917	13.464	.074274	.6	.30064	1998.2	.000500
.7	.17260	14.880	.067206	.7	.34407	2208.3	.000453
.8	.21602	16.445	.060810	.8	.38750	2440.6	.000410
.9	.25945	18.174	.055023	.9	.43093	2697.3	.000371
3.0	1.30288	20.086	0.049787	8.0	3.47436	2981.0	0.000335
.1	.34631	22.198	.045049	.1	.51779	3294.5	.000304
.2	.38974	24.533	.040762	.2	.56121	3641.0	.000275
.3	.43317	27.113	.036883	.3	.60464	4023.9	.000249
.4	.47660	29.964	.033373	.4	.64807	4447.1	.000225
3.5	1.52003	33.115	0.030197	8.5	3.69150	4914.8	0.000203
.6	.56346	36.598	.027324	.6	.73493	5431.7	.000184
.7	.60689	40.447	.024724	.7	.77836	6002.9	.000167
.8	.65032	44.701	.022371	.8	.82179	6634.2	.000151
.9	.69375	49.402	.020242	.9	.86522	7332.0	.000136
4.0	1.73718	54.598	0.018316	9.0	3.90865	8103.1	0.000123
.1	.78061	60.340	.016573	.1	.95208	8955.3	.000112
.2	.82404	66.686	.014996	.2	.99551	9897.1	.000101
.3	.86747	73.700	.013569	.3	4.03894	10938.	.000091
.4	.91090	81.451	.012277	.4	.08237	12088.	.000083
4.5	1.95433	90.017	0.011109	9.5	4.12580	13360.	0.000075
.6	.99775	99.484	.010052	.6	.16923	14765.	.000068
.7	2.04118	109.95	.009095	.7	.21266	16318.	.000061
.8	.08461	121.51	.008230	.8	.25609	18034.	.000055
.9	.12804	134.29	.007447	.9	.29952	19930.	.000050
5.0	2.17147	148.41	0.006738	10.0	4.34294	22026.	0.000045

Taken from Glaisher's 'Tables of the Exponential Function,' Trans. Cambridge Phil. Soc. vol. xiii. 1883. This volume also contains a 'Table of the Descending Exponential to Twelve or Fourteen Places of Decimals,' by F. W. Newman.

EXPONENTIAL FUNCTIONS, LOG e^x.

x	$\log_{10}(e^x)$	x	$\log_{10}(e^x)$	x	$\log_{10}(e^x)$	x	$\log_{10}(e^x)$
10.0	4.34294	15.0	6.51442	20.0	8.68589	25.0	10.85736
.1	.38637	.1	.55785	.1	.72932	.1	.90079
.2	.42980	.2	.60128	.2	.77275	.2	.94422
.3	.47323	.3	.64471	.3	.81618	.3	.98765
.4	.51666	.4	.68814	.4	.85961	.4	11.03108
10.5	4.56009	15.5	6.73156	20.5	8.90304	25.5	11.07451
.6	.60352	.6	.77499	.6	.94647	.6	.11794
.7	.64695	.7	.81842	.7	.98990	.7	.16137
.8	.69038	.8	.86185	.8	9.03333	.8	.20480
.9	.73381	.9	.90528	.9	.07675	.9	.24823
11.0	4.77724	16.0	6.94871	21.0	9.12018	26.0	11.29166
.1	.82067	.1	.99214	.1	.16361	.1	.33509
.2	.86410	.2	7.03557	.2	.20704	.2	.37852
.3	.90753	.3	.07900	.3	.25047	.3	.42194
.4	.95096	.4	.12243	.4	.29390	.4	.46537
11.5	4.99439	16.5	7.16586	21.5	9.33733	26.5	11.50880
.6	5.03782	.6	.20929	.6	.38076	.6	.55223
.7	.08125	.7	.25272	.7	.42419	.7	.59566
.8	.12467	.8	.29615	.8	.46762	.8	.63909
.9	.16810	.9	.33958	.9	.51105	.9	.68252
12.0	5.21153	17.0	7.38301	22.0	9.55448	27.0	11.72595
.1	.25496	.1	.42644	.1	.59791	.1	.76938
.2	.29839	.2	.46987	.2	.64134	.2	.81281
.3	.34182	.3	.51329	.3	.68477	.3	.85624
.4	.38525	.4	.55672	.4	.72820	.4	.89967
12.5	5.42868	17.5	7.60015	22.5	9.77163	27.5	11.94310
.6	.47211	.6	.64358	.6	.81506	.6	.98653
.7	.51554	.7	.68701	.7	.85848	.7	12.02996
.8	.55897	.8	.73044	.8	.90191	.8	.07339
.9	.60240	.9	.77387	.9	.94534	.9	.11682
13.0	5.64583	18.0	7.81730	23.0	9.98877	28.0	12.16025
.1	.68926	.1	.86073	.1	10.03220	.1	.20367
.2	.73269	.2	.90416	.2	.07563	.2	.24710
.3	.77612	.3	.94759	.3	.11906	.3	.29053
.4	.81955	.4	.99102	.4	.16249	.4	.33396
13.5	5.86298	18.5	8.03445	23.5	10.20592	28.5	12.37739
.6	.90640	.6	.07788	.6	.24935	.6	.42082
.7	.94983	.7	.12131	.7	.29278	.7	.46425
.8	5.99326	.8	.16474	.8	.33621	.8	.50768
.9	6.03669	.9	.20817	.9	.37964	.9	.55111
14.0	6.08012	19.0	8.25160	24.0	10.42307	29.0	12.59454
.1	.12355	.1	.29502	.1	.46650	.1	.63797
.2	.16698	.2	.33845	.2	.50993	.2	.68140
.3	.21041	.3	.38188	.3	.55336	.3	.72483
.4	.25384	.4	.42531	.4	.59679	.4	.76826
14.5	6.29727	19.5	8.46874	24.5	10.64021	29.5	12.81169
.6	.34070	.6	.51217	.6	.68364	.6	.85512
.7	.38413	.7	.55560	.7	.72707	.7	.89855
.8	.42756	.8	.59903	.8	.77050	.8	.94198
.9	.47099	.9	.64246	.9	.81393	.9	.98541
15.0	6.51442	20.0	8.68589	25.0	10.85736	30.0	13.02883

EXPONENTIAL FUNCTIONS.

Value of e^{x^2} and e^{-x^2} and their logarithms.

The equation to the probability curve is $y = e^{-x^2}$, where x may have any value, positive or negative, between zero and infinity.

x	e^{x^2}	$\log e^{x^2}$	e^{-x^2}	$\log e^{-x^2}$
0.1	1.0101	0.00434	0.99005	$\bar{1}$.99566
2	1.0408	01737	96079	98263
3	1.0904	03909	91393	96091
4	1.1735	06949	85214	93051
5	1.2840	10857	77880	89143
0.6	1.4333	0.15635	0.69768	$\bar{1}$.84365
7	1.6323	21280	61263	78720
8	1.8965	27795	52729	72205
9	2.2479	35178	44486	64822
1.0	2.7183	43429	36788	56571
1.1	3.3535	0.52550	0.29820	$\bar{1}$.47450
2	4.2207	62538	23693	37462
3	5.4195	73396	18452	26604
4	7.0993	85122	14086	14878
5	9.4877	97716	10540	02284
1.6	1.2936×10	1.11179	0.77306×10^{-1}	$\bar{2}$.88821
7	1.7993 "	25511	55576 "	74489
8	2.5534 "	40711	39164 "	59289
9	3.6996 "	56780	27052 "	43220
2.0	5.4598 "	73718	18316 "	26282
2.1	8.2269 "	1.91524	0.12155 "	$\bar{2}$.08476
2	1.2647×10^{2}	2.10199	79070×10^{-2}	$\bar{3}$.89801
3	1.9834 "	29742	50418 "	70258
4	3.1735 "	50154	31511 "	49846
5	5.1802 "	71434	19304 "	28566
2.6	8.6264 "	2.93583	0.11592 "	$\bar{3}$.06417
7	1.4656×10^{3}	3.16601	68233×10^{-3}	4.83400
8	2.5402 "	40487	39367 "	59513
9	4.4918 "	65242	22263 "	34758
3.0	8.1031 "	90865	12341 "	09135
3.1	1.4913×10^{4}	4.17357	0.67055×10^{-4}	$\bar{5}$.82643
2	2.8001 "	44718	35713 "	55283
3	5.3638 "	72947	18644 "	27053
4	1.0482×10^{5}	5.02044	95402×10^{-5}	$\bar{6}$.97956
5	2.0898 "	32011	47851 "	67989
3.6	4.2507 "	5.62846	0.23526 "	$\bar{6}$.37154
7	8.8205 "	94549	11337 "	05451
8	1.8673×10^{6}	6.27121	53554×10^{-6}	$\bar{7}$.72879
9	4.0329 "	60562	24796 "	39438
4.0	8.8861 "	94871	11254 "	05129
4.1	1.9976×10^{7}	7.30049	0.50062×10^{-7}	$\bar{8}$.69951
2	4.5809 "	66095	21829 "	33905
3	1.0718×10^{8}	8.03011	93303×10^{-8}	$\bar{9}$.96989
4	2.5583 "	40796	39088 "	59204
5	6.2297 "	79447	16052 "	20553
4.6	1.5476×10^{9}	9.18967	0.64614×10^{-9}	$\bar{10}$.81033
7	3.9228 "	59357	25494 "	40643
8	1.0143×10^{10}	10.00615	98595×10^{-10}	$\bar{11}$.99385
9	2.6755 "	42741	37376 "	57259
5.0	7.2005 "	85736	13888 "	14264

TABLE 20.

EXPONENTIAL FUNCTIONS.

Values of $e^{\frac{\pi}{4}x}$ and $e^{-\frac{\pi}{4}x}$ and their logarithms.

x	$e^{\frac{\pi}{4}x}$	$\log e^{\frac{\pi}{4}x}$	$e^{-\frac{\pi}{4}x}$	$\log e^{-\frac{\pi}{4}x}$
1	2.1933	0.34109	0.45594	$\bar{1}.65891$
2	4.8105	.68219	.20788	.31781
3	1.0551×10	1.02328	$.94780 \times 10^{-1}$	$\bar{2}.97672$
4	2.3141 "	.36438	.43214 "	.63562
5	5.0754 "	.70547	.19703 "	.29453
6	1.1132×10^{2}	2.04656	0.89833×10^{-2}	$\bar{3}.95344$
7	2.4415 "	.38766	.40958 "	.61234
8	5.3549 "	.72875	.18674 "	.27125
9	1.1745×10^{3}	3.06985	$.85144 \times 10^{-3}$	$\bar{4}.93015$
10	2.5760 "	.41094	.38820 "	.58906
11	5.6498 "	3.75204	0.17700 "	$\bar{4}.24796$
12	1.2392×10^{4}	4.09313	$.80699 \times 10^{-4}$	$\bar{5}.90687$
13	2.7168 "	.43422	.36794 "	.56578
14	5.9610 "	.77532	.16776 "	.22468
15	1.3074×10^{5}	5.11641	$.76487 \times 10^{-5}$	$\bar{6}.88359$
16	2.8675 "	5.45751	0.34873 "	$\bar{6}.54249$
17	6.2893 "	.79860	.15900 "	.20140
18	1.3794×10^{6}	6.13969	$.72495 \times 10^{-6}$	$\bar{7}.86031$
19	3.0254 "	.48079	.33053 "	.51921
20	6.6356 "	.82189	.15070 "	.17812

TABLE 21.

EXPONENTIAL FUNCTIONS.

Values of $e^{\frac{\sqrt{\pi}}{4}x}$ and $e^{-\frac{\sqrt{\pi}}{4}x}$ and their logarithms.

x	$e^{\frac{\sqrt{\pi}}{4}x}$	$\log e^{\frac{\sqrt{\pi}}{4}x}$	$e^{-\frac{\sqrt{\pi}}{4}x}$	$\log e^{-\frac{\sqrt{\pi}}{4}x}$
1	1.5576	0.19244	0.64203	$\bar{1}.80756$
2	2.4260	.38488	.41221	.61512
3	3.7786	.57733	.26465	.42267
4	5.8853	.76977	.16992	.23023
5	9.1666	.96221	.10909	.03779
6	14.277	1.15465	0.070041	$\bar{2}.84535$
7	22.238	.34709	.044968	.65291
8	34.636	.53953	.028871	.46047
9	53.948	.73198	.018536	.26802
10	84.027	.92442	.011901	.07558
11	130.87	2.11686	0.0076408	$\bar{3}.88314$
12	203.85	.30930	.0049057	.69070
13	317.50	.50174	.0031496	.49826
14	494.52	.69418	.0020222	.30582
15	770.24	.88663	.0012983	.11337
16	1199.7	3.07907	0.00083355	$\bar{4}.92093$
17	1868.5	.27151	.00053517	.72849
18	2910.4	.46395	.00034360	.53605
19	4533.1	.65639	.00022060	.34361
20	7060.5	.84883	.00014163	.15117

TABLE 22. — Exponential Functions.

Value of e^x and e^{-x} and their logarithms.

x	e^x	log e^x	e^{-x}	x	e^x	log e^x	e^{-x}
1/64	1.0157	0.00679	0.98450	1/3	1.3956	0.14476	0.71653
1/32	.0317	.01357	.96923	1/2	.6487	.21715	.60653
1/16	.0645	.02714	.93941	3/4	2.1170	.32572	.47237
1/10	.1052	.04343	.90484	1	.7183	.43429	.36788
1/9	.1175	.04825	.89484	5/4	3.4903	.54287	.28650
1/8	1.1331	0.05429	0.88250	3/2	4.4817	0.65144	0.22313
1/7	.1536	.06204	.86688	7/4	5.7546	.76002	.17377
1/6	.1814	.07238	.84648	2	7.3891	.86859	.13535
1/5	.2214	.08686	.81873	9/4	9.4877	.97716	.10540
1/4	.2840	.10857	.77880	5/2	12.1825	1.08574	.08208

TABLE 23. — Least Squares.

Values of $P = \frac{2}{\sqrt{\pi}} \int_0^{hx} e^{-(hx)^2} d(hx)$.

This table gives the value of P, the probability of an observational error having a value positive or negative equal to or less than x when h is the measure of precision, $P = \frac{2}{\sqrt{\pi}} \int_0^{hx} e^{-(hx)^2} d(hx)$. For values of the inverse function see the table on Diffusion.

hx	1	2	3	4	5	6	7	8	9	10
0.0	.01128	.02256	.03384	.04511	.05637	.06762	.07886	.09008	.10128	.11246
.1	.12362	.13476	.14587	.15695	.16800	.17901	.18999	.20094	.21184	.22270
.2	.23352	.24430	.25502	.26570	.27633	.28690	.29742	.30788	.31828	.32863
.3	.33891	.34913	.35928	.36936	.37938	.38933	.39921	.40901	.41874	.42839
.4	.43797	.44747	.45689	.46623	.47548	.48466	.49375	.50275	.51167	.52050
0.5	.52924	.53790	.54646	.55494	.56332	.57162	.57982	.58792	.59594	.60386
.6	.61168	.61941	.62705	.63459	.64203	.64938	.65663	.66378	.67084	.67780
.7	.68467	.69143	.69810	.70468	.71116	.71754	.72382	.73001	.73610	.74210
.8	.74800	.75381	.75952	.76514	.77067	.77610	.78144	.78669	.79184	.79691
.9	.80188	.80677	.81156	.81627	.82089	.82542	.82987	.83423	.83851	.84270
1.0	.84681	.85084	.85478	.85865	.86244	.86614	.86977	.87333	.87680	.88021
.1	.88353	.88679	.88997	.89308	.89612	.89910	.90200	.90484	.90761	.91031
.2	.91296	.91553	.91805	.92051	.92290	.92524	.92751	.92973	.93190	.93401
.3	.93606	.93807	.94002	.94191	.94376	.94556	.94731	.94902	.95067	.95229
.4	.95385	.95538	.95686	.95830	.95970	.96105	.96237	.96365	.96490	.96611
1.5	.96728	.96841	.96952	.97059	.97162	.97263	.97360	.97455	.97546	.97635
.6	.97721	.97804	.97884	.97962	.98038	.98110	.98181	.98249	.98315	.98379
.7	.98441	.98500	.98558	.98613	.98667	.98719	.98769	.98817	.98864	.98909
.8	.98952	.98994	.99035	.99074	.99111	.99147	.99182	.99216	.99248	.99279
.9	.99309	.99338	.99366	.99392	.99418	.99443	.99466	.99489	.99511	.99532
2.0	.99552	.99572	.99591	.99609	.99626	.99642	.99658	.99673	.99688	.99702
.1	.99715	.99728	.99741	.99753	.99764	.99775	.99785	.99795	.99805	.99814
.2	.99822	.99831	.99839	.99846	.99854	.99861	.99867	.99874	.99880	.99886
.3	.99891	.99897	.99902	.99906	.99911	.99915	.99920	.99924	.99928	.99931
.4	.99935	.99938	.99941	.99944	.99947	.99950	.99952	.99955	.99957	.99959
2.5	.99961	.99963	.99965	.99967	.99969	.99971	.99972	.99974	.99975	.99976
.6	.99978	.99979	.99980	.99981	.99982	.99983	.99984	.99985	.99986	.99987
.7	.99987	.99988	.99989	.99989	.99990	.99991	.99991	.99992	.99992	.99992
.8	.99993	.99993	.99994	.99994	.99994	.99995	.99995	.99995	.99996	.99996
.9	.99996	.99996	.99997	.99997	.99997	.99997	.99997	.99997	.99998	.99998
3.0	.99999	.99999	1.00000							

Taken from a paper by Dr. James Burgess 'on the Definite Integral $\frac{2}{\sqrt{\pi}} \int_0^t e^{-t^2} dt$, with Extended Tables of Values.' Trans. Roy. Soc. of Edinburgh, vol. xxxix, 1900, p. 257.

TABLE 24.

LEAST SQUARES.

This table gives the values of the probability P, as defined in last table, corresponding to different values of x/r where r is the "probable error." The probable error r is equal to $0.47694/h$.

$\frac{x}{r}$	0	1	2	3	4	5	6	7	8	9
0.0	.00000	.00538	.01076	.01614	.02152	.02690	.03228	.03766	.04303	.04840
0.1	.05378	.05914	.06451	.06987	.07523	.08059	.08594	.09129	.09663	.10197
0.2	.10731	.11264	.11796	.12328	.12860	13391	.13921	.14451	.14980	.15508
0.3	.16035	.16562	.17088	.17614	.18138	.18662	.19185	.19707	.20229	.20749
0.4	.21268	.21787	.22304	.22821	.23336	.23851	.24364	.24876	.25388	.25898
0.5	.26407	.26915	.27421	.27927	.28431	.28934	.29436	.29936	.30435	.30933
0.6	.31430	.31925	.32419	.32911	.33402	.33892	.34380	.34866	.35352	.35835
0.7	.36317	.36798	.37277	.37755	.38231	.38705	.39178	.39649	.40118	.40586
0.8	.41052	.41517	.41979	.42440	.42899	.43357	.43813	.44267	.44719	.45169
0.9	.45618	.46064	.46509	.46952	.47393	.47832	.48270	48605	.49139	.49570
1.0	.50000	.50428	.50853	.51277	.51699	.52119	.52537	.52952	.53366	.53778
1.1	.54188	.54595	.55001	.55404	.55806	.56205	.56602	.56998	.57391	.57782
1.2	.58171	.58558	.58942	.59325	.59705	.60083	.60460	.60833	.61205	.61575
1.3	.61942	.62308	.62671	.63032	.63391	.63747	.64102	.64554	.64804	.65152
1.4	.65498	.65841	.66182	.66521	.66858	.67193	.67526	.67856	.68184	.68510
1.5	.68833	.69155	.69474	.69791	.70106	.70419	.70729	.71038	.71344	.71648
1.6	.71949	.72249	.72546	.72841	.73134	.73425	.73714	.74000	.74285	.74567
1.7	.74847	.75124	.75400	.75674	.75945	.76214	.76481	.76746	.77009	.77270
1.8	.77528	.77785	.78039	.78291	.78542	.78790	.79036	.79280	.79522	.79761
1.9	.79999	.80235	.80469	.80700	.80930	.81158	.81383	.81607	.81828	.82048
2.0	.82266	.82481	.82695	.82907	.83117	.83324	.83530	.83734	.83936	.84137
2.1	.84335	.84531	.84726	.84919	.85109	.85298	.85486	.85671	.85854	.86036
2.2	.86216	.86394	.86570	.86745	.86917	.87088	.87258	.87425	.87591	.87755
2.3	.87918	.88078	.88237	.88395	.88550	.88705	.88857	.89008	.89157	.89304
2.4	.89450	.89595	.89738	.89879	.90019	.90157	.90293	.90428	.90562	.90694
2.5	.90825	.90954	.91082	.91208	.91332	.91456	.91578	.91698	.91817	.91935
2.6	.92051	.92166	.92280	.92392	.92503	.92613	.92721	.92828	.92934	.93038
2.7	.93141	.93243	.93344	.93443	.93541	.93638	.93734	.93828	.93922	.94014
2.8	.94105	.94195	.94284	.94371	.94458	.94543	.94627	.94711	.94793	.94874
2.9	.94954	.95033	.95111	.95187	.95263	.95338	.95412	.95484	.95557	.95628
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
3	.95698	.96346	.96910	.97397	.97817	.98176	.98482	.98743	.98962	.99147
4	.99302	.99431	.99539	99627	.99700	.99760	.99808	.99848	.99879	.99905
5	.99926	.99943	.99956	.99966	.99974	.99980	.99985	.99988	.99991	.99993

TABLE 25.

LEAST SQUARES.

Values of the factor $0.6745\sqrt{\frac{1}{n-1}}$.

This factor occurs in the equation $\epsilon_s = 0.6745\sqrt{\frac{\Sigma v^2}{n-1}}$ for the probable error of a single observation, and other similar equations.

n =	1	2	3	4	5	6	7	8	9
00		0.6745	0.4769	0.3894	0.3372	0.3016	0.2754	0.2549	0.2385
10	0.2248	.2029	.1947	.1871	.1803	.1742	.1686	.1636	.1590
20	.1547	.1508	.1472	.1438	.1406	.1377	.1349	.1323	.1298	.1275
30	.1252	.1231	.1211	.1192	.1174	.1157	.1140	.1124	.1109	.1094
40	.1080	.1066	.1053	.1041	.1029	.1017	.1005	.0994	.0984	.0974
50	0.0964	0.0954	0.0944	0.0935	0.0926	0.0918	0.0909	0.0901	0.0893	0.0886
60	.0878	.0871	.0864	.0857	.0850	.0843	.0837	.0830	.0824	.0818
70	.0812	.0806	.0800	.0795	.0789	.0784	.0778	.0773	.0768	.0763
80	.0759	.0754	.0749	.0745	.0740	.0736	.0731	.0727	.0723	.0719
90	.0715	.0711	.0707	.0703	.0699	.0696	.0692	.0688	.0685	.0681

TABLE 26.

LEAST SQUARES.

Values of the factor $0.6745\sqrt{\frac{1}{n(n-1)}}$.

This factor occurs in the equation $\epsilon_m = 0.6745\sqrt{\frac{\Sigma y^2}{n(n-1)}}$ for the probable error of the arithmetic mean.

n =	1	2	3	4	5	6	7	8	9
00		0.4769	0.2754	0.1947	0.1508	0.1231	0.1041	0.0901	0.0795
10	0.0711	.0587	.0540	.0500	.0465	.0435	.0409	.0386	.0365
20	.0346	.0329	.0314	.0300	.0287	.0275	.0265	.0255	.0245	.0237
30	0.0229	0.0221	0.0214	0.0208	0.0201	0.0196	0.0190	0.0185	0.0180	0.0175
40	.0171	.0167	.0163	.0159	.0155	.0152	.0148	.0145	.0142	.0139
50	.0136	.0134	.0131	.0128	.0126	.0124	.0122	.0119	.0117	.0115

TABLE 27.

LEAST SQUARES.

Values of the factor $0.8453\sqrt{\frac{1}{n(n-1)}}$.

This factor occurs in the equation $\epsilon_s = 0.8453\frac{\Sigma y}{\sqrt{n(n-1)}}$ for the probable error of a single observation.

n =	1	2	3	4	5	6	7	8	9
00		0.5978	0.3451	0.2440	0.1890	0.1543	0.1304	0.1130	0.0996
10	0.0891	0.0806	.0736	.0677	.0627	.0583	.0546	.0513	.0483	.0457
20	.0434	.0412	.0393	.0376	.0360	.0345	.0332	.0319	.0307	.0297
30	0.0287	0.0277	0.0268	0.0260	0.0252	0.0245	0.0238	0.0232	0.0225	0.0220
40	.0214	.0209	.0204	.0199	.0194	.0190	.0186	.0182	.0178	.0174
50	.0171	.0167	.0164	.0161	.0158	.0155	.0152	.0150	.0147	.0145

TABLE 28.

LEAST SQUARES.

Values of $0.8453\frac{1}{n\sqrt{n-1}}$.

This table gives the average error of the arithmetic mean when the probable error is one.

n =	1	2	3	4	5	6	7	8	9
00		0.4227	0.1993	0.1220	0.0845	0.0630	0.0493	0.0399	0.0332
10	0.0282	0.0243	.0212	.0188	.0167	.0151	.0136	.0124	.0114	.0105
20	.0097	.0090	.0084	.0078	.0073	.0069	.0065	.0061	.0058	.0055
30	0.0052	0.0050	0.0047	0.0045	0.0043	0.0041	0.0040	0.0038	0.0037	0.0035
40	.0034	.0033	.0031	.0030	.0029	.0028	.0027	.0027	.0026	.0025
50	.0024	.0023	.0023	.0022	.0022	.0021	.0020	.0020	.0019	.0019

TABLE 29.
DIFFUSION.

Inverse* values of $v/c = 1 - \frac{2}{\sqrt{\pi}} \int_0^q e^{-q^2} dq$.

$\log x = \log(2q) + \log\sqrt{kt}$. t expressed in seconds.

$= \log \delta + \log\sqrt{kt}$. t expressed in days.

$= \log \gamma + \log\sqrt{kt}$. " " years.

k = coefficient of diffusion.†

c = initial concentration.

v = concentration at distance x, time t.

v/c	$\log 2q$	$2q$	$\log \delta$	δ	$\log \gamma$	γ
0.00	$+\infty$	$+\infty$	$+\infty$	$+\infty$	∞	∞
.01	0.56143	3.6428	3.02970	1070.78	4.31098	20463.
.02	.51719	3.2900	2.98545	967.04	.26674	18481.
.03	.48699	3.0690	.95525	902.90	.23654	17240.
.04	.46306	2.9044	.93132	853.73	.21261	16316.
0.05	0.44276	2.7718	2.91102	814.74	4.19231	15571.
.06	.42486	2.6598	.89311	781.83	.17440	14942.
.07	.40865	2.5624	.87691	753.20	.15820	14395.
.08	.39372	2.4758	.86198	727.75	.14327	13908.
.09	.37979	2.3977	.84804	704.76	.12933	13469.
0.10	0.36664	2.3262	2.83490	683.75	4.11619	13067.
.11	.35414	2.2602	.82240	664.36	.10369	12697.
.12	.34218	2.1988	.81044	646.31	.09173	12352.
.13	.33067	2.1413	.79893	629.40	.08022	12029.
.14	.31954	2.0871	.78780	613.47	.06909	11724.
0.15	0.30874	2.0358	2.77699	598.40	4.05828	11436.
.16	.29821	1.9871	.76647	584.08	.04776	11162.
.17	.28793	1.9406	.75619	570.41	.03748	10901.
.18	.27786	1.8961	.74612	557.34	.02741	10652.
.19	.26798	1.8534	.73624	544.80	.01753	10412.
0.20	0.25825	1.8124	2.72651	532.73	4.00780	10181.
.21	.24866	1.7728	.71692	521.10	3.99821	9958.9
.22	.23919	1.7346	.70745	509.86	.98874	9744.1
.23	.22983	1.6976	.69808	498.98	.97937	9536.2
.24	.22055	1.6617	.68880	488.43	.97010	9334.6
0.25	0.21134	1.6268	2.67960	478.19	3.96089	9138.9
.26	.20220	1.5930	.67046	468.23	.95175	8948.5
.27	.19312	1.5600	.66137	458.53	.94266	8763.2
.28	.18407	1.5278	.65232	449.08	.93361	8582.5
.29	.17505	1.4964	.64331	439.85	.92460	8406.2
0.30	0.16606	1.4657	2.63431	430.84	3.91560	8233.9
.31	.15708	1.4357	.62533	422.02	.90662	8065.4
.32	.14810	1.4064	.61636	413.39	.89765	7900.4
.33	.13912	1.3776	.60738	404.93	.88867	7738.8
.34	.13014	1.3494	.59840	396.64	.87969	7580.3
0.35	0.12114	1.3217	2.58939	388.50	3.87068	7424.8
.36	.11211	1.2945	.58037	380.51	.86166	7272.0
.37	.10305	1.2678	.57131	372.66	.85260	7122.0
.38	.09396	1.2415	.56222	364.93	.84351	6974.4
.39	.08482	1.2157	.55308	357.34	.83437	6829.2
0.40	0.07563	1.1902	2.54389	349.86	3.82518	6686.2
.41	.06639	1.1652	.53464	342.49	.81593	6545.4
.42	.05708	1.1405	.52533	335.22	.80662	6406.6
.43	.04770	1.1161	.51595	328.06	.79724	6269.7
.44	.03824	1.0920	.50650	320.99	.78779	6134.6
0.45	0.02870	1.0683	2.49696	314.02	3.77825	6001.3
.46	.01907	1.0449	.48733	307.13	.76862	5869.7
.47	.00934	1.0217	.47760	300.33	.75889	5739.7
.48	9.99951	0.99886	.46776	293.60	.74905	5611.2
.49	.98956	0.97624	.45782	286.96	.73911	5484.1
0.50	9.97949	0.95387	2.44775	280.38	3.72904	5358.4

* Kelvin, Mathematical and Physical Papers, vol. III. p. 428; Becker, Am. Jour. of Sci. vol. III. 1897, p. 280. † For direct values see table 23.

Taken from unpublished manuscript of C. E. Van Orstrand.

DIFFUSION.

v/c	log $2q$	$2q$	log δ	δ	log γ	γ
0.50	9.97949	0.95387	2.44775	280.38	3.72904	5358.4
.51	.96929	.93174	.43755	273.87	.71884	5234.1
.52	.95896	.90983	.42722	267.43	.70851	5111.0
.53	.94848	.88813	.41674	261.06	.69803	4989.1
.54	.93784	.86665	.40610	254.74	.68739	4868.4
0.55	9.92704	0.84536	2.39530	248.48	3.67659	4748.9
.56	.91607	.82426	.38432	242.28	.66561	4630.3
.57	.90490	.80335	.37316	236.13	.65445	4512.8
.58	.89354	.78260	.36180	230.04	.64309	4396.3
.59	.88197	.76203	.35023	223.99	.63152	4280.7
0.60	9.87018	0.74161	2.33843	217.99	3.61973	4166.1
.61	.85815	.72135	.32640	212.03	.60770	4052.2
.62	.84587	.70124	.31412	206.12	.59541	3939.2
.63	.83332	.68126	.30157	200.25	.58286	3827.0
.64	.82048	.66143	.28874	194.42	.57003	3715.6
0.65	9.80734	0.64172	2.27560	188.63	3.55689	3604.9
.66	.79388	.62213	.26214	182.87	.54343	3494.9
.67	.78008	.60266	.24833	177.15	.52962	3385.4
.68	.76590	.58331	.23416	171.46	.51545	3276.8
.69	.75133	.56407	.21959	165.80	.50088	3168.7
0.70	9.73634	0.54493	2.20459	160.17	3.48588	3061.1
.71	.72089	.52588	.18915	154.58	.47044	2954.2
.72	.70495	.50694	.17321	149.01	.45450	2847.7
.73	.68849	.48808	.15675	143.47	.43804	2741.8
.74	.67146	.46931	.13972	137.95	.42101	2636.4
0.75	9.65381	0.45062	2.12207	132.46	3.40336	2531.4
.76	.63550	.43202	.10376	126.99	.38505	2426.9
.77	.61646	.41348	.08471	121.54	.36600	2322.7
.78	.59662	.39502	.06487	116.11	.34616	2219.0
.79	.57590	.37662	.04416	110.70	.32545	2115.7
0.80	9.55423	0.35829	2.02249	105.31	3.30378	2012.7
.81	.53150	.34001	1.99975	99.943	.28104	1910.0
.82	.50758	.32180	.97584	94.589	.25713	1807.7
.83	.48235	.30363	.95061	89.250	.23190	1705.7
.84	.45564	.28552	.92389	83.926	.20518	1603.9
0.85	9.42725	0.26745	1.89551	78.615	3.17680	1502.4
.86	.39695	.24943	.86521	73.317	.14650	1401.2
.87	.36445	.23145	.83271	68.032	.11400	1300.2
.88	.32940	.21350	.79766	62.757	.07895	1199.4
.89	.29135	.19559	.75961	57.492	3.04090	1098.7
0.90	9.24972	0.17771	1.71797	52.236	2.99926	998.31
.91	.20374	.15986	.67200	46.989	.95329	898.03
.92	.15239	.14203	.62065	41.750	.90194	797.89
.93	.09423	.12423	.56249	36.516	.84378	697.88
.94	9.02714	.10645	.49539	31.289	.77668	597.98
0.95	8.94783	0.08868	1.41609	26.067	2.69738	498.17
.96	.85082	.07093	.31907	20.848	.60036	398.44
.97	.72580	.05319	.19406	15.633	.47535	298.78
.98	.54965	.03545	.01791	10.421	.29920	199.16
.99	.24859	.01773	9.71684	5.21007	1.99813	99.571
1.00	$-\infty$	0.00000	$-\infty$	0.00000	$-\infty$	0.000

GAMMA FUNCTION.*

Value of $\log \int_0^\infty e^{-x} x^{n-1} dx + 10$.

Values of the logarithms + 10 of the "Second Eulerian Integral" (Gamma function) $\int_0^\infty e^{-x} x^{n-1} dx$ or $\log \Gamma(n) + 10$ for values of n between 1 and 2. When n has values not lying between 1 and 2 the value of the function can be readily calculated from the equation $\Gamma(n+1) = n\Gamma(n) = n(n-1) \ldots (n-r)\Gamma(n-r)$.

n	0	1	2	3	4	5	6	7	8	9
1.00	9.99———	97497	95001	92512	90030	87555	85087	82627	80173	77727
1.01	75287	72855	70430	68011	65600	63196	60799	58408	56025	53648
1.02	51279	48916	46561	44212	41870	39535	37207	34886	32572	30265
1.03	27964	25671	23384	21104	18831	16564	14305	12052	09806	07567
1.04	05334	03108	00889	98677	96471	94273	92080	89895	87716	85544
1.05	9.9883379	81220	79068	76922	74783	72651	70525	68406	66294	64188
1.06	62089	59996	57910	55830	53757	51690	49630	47577	45530	43489
1.07	41469	39428	37407	35392	33384	31382	29387	27398	25415	23449
1.08	21469	19506	17549	15599	13655	11717	09785	07860	05941	04029
1.09	02123	00223	98329	96442	94561	92686	90818	89856	87100	85250
1.10	9.9783407	81570	79738	77914	76095	74283	72476	70676	68882	67095
1.11	65313	63538	61768	60005	58248	56497	54753	53014	51281	49555
1.12	47834	46120	44411	42709	41013	39323	37638	35960	34288	32622
1.13	30962	29308	27659	26017	24381	22751	21126	19508	17896	16289
1.14	14689	13094	11505	09922	08345	06774	05209	03650	02096	00549
1.15	9.9699007	97471	95941	94417	92898	91386	89879	88378	86883	85393
1.16	83910	82432	80960	79493	78033	76578	75129	73686	72248	70816
1.17	69390	67969	66554	65145	63742	62344	60952	59566	58185	56810
1.18	55440	54076	52718	51366	50019	48677	47341	46011	44687	43368
1.19	42054	40746	39444	38147	36856	35570	34290	33016	31747	30483
1.20	9.9629225	27973	26725	25484	24248	23017	21792	20573	19358	18150
1.21	16946	15748	14556	13369	12188	11011	09841	08675	07515	06361
1.22	05212	04068	02930	01796	00669	99546	98430	97318	96212	95111
1.23	594015	92925	91840	90760	89685	88616	87553	86494	85441	84393
1.24	83350	82313	81280	80253	79232	78215	77204	76198	75197	74201
1.25	9.9573211	72226	71246	70271	69301	68337	67377	66423	65474	64530
1.26	63592	62658	61730	60806	59888	58975	58067	57165	56267	55374
1.27	54487	53604	52727	51855	50988	50126	49268	48416	47570	46728
1.28	45891	45059	44232	43410	42593	41782	40975	40173	39376	38585
1.29	37798	37016	36239	35467	34700	33938	33181	32439	31682	30940
1.30	9.9530203	29470	28743	28021	27303	26590	25883	25180	24482	23789
1.31	23100	22417	21739	21065	20396	19732	19073	18419	17770	17125
1.32	16485	15850	15220	14595	13975	13359	12748	12142	11540	10944
1.33	10353	09766	09184	08606	08034	07466	06903	06344	05791	05242
1.34	04698	04158	03624	03094	02568	02048	01532	01021	00514	00012
1.35	9.9499515	99023	98535	98052	97573	97100	96630	96166	95706	95251
1.36	94800	94355	93913	93477	93044	92617	92194	91776	91362	90953
1.37	90549	90149	89754	89363	88977	88595	88218	87846	87478	87115
1.38	86756	86402	86052	85707	85366	85030	84698	84371	84049	83731
1.39	83417	83108	82803	82503	82208	81916	81630	81348	81070	80797
1.40	9.9480528	80263	80003	79748	79497	79250	79008	78770	78537	78308
1.41	78084	77864	77648	77437	77230	77027	76829	76636	76446	76261
1.42	76081	75905	75733	75565	75402	75243	75089	74939	74793	74652
1.43	74515	74382	74254	74130	74010	73894	73783	73676	73574	73746
1.44	73382	73292	73207	73125	73049	72976	72908	72844	72784	72728

* Quoted from Carr's "Synopsis of Mathematics," and is there quoted from Legendre's "Exercises de Calcul Intégral," tome ii.

GAMMA FUNCTION.

n	0	1	2	3	4	5	6	7	8	9
1.45	9.9472677	72630	72587	72549	72514	72484	72459	72437	72419	72406
1.46	72397	72393	72392	72396	72404	72416	72432	72452	72477	72506
1.47	72539	72576	72617	72662	72712	72766	72824	72886	72952	73022
1.48	73097	73175	73258	73345	73436	73531	73630	73734	73841	73953
1.49	74068	74188	74312	74440	74572	74708	74848	74992	75141	75293
1.50	9.9475449	75610	75774	75943	76116	76292	76473	76658	76847	77040
1.51	77237	77438	77642	77851	78064	78281	78502	78727	78956	79189
1.52	79426	79667	79912	80161	80414	80671	80932	81196	81465	81738
1.53	82015	82295	82580	82868	83161	83457	83758	84062	84370	84682
1.54	84998	85318	85642	85970	86302	86638	86977	87321	87668	88019
1.55	9.9488374	88733	89096	89463	89834	90208	90587	90969	91355	91745
1.56	92139	92537	92938	93344	93753	94166	94583	95004	95429	95857
1.57	96289	96725	97165	97609	98056	98508	98963	99422	99885	00351
1.58	500822	01296	01774	02255	02741	03230	03723	04220	04720	05225
1.59	05733	06245	06760	07280	07803	08330	08860	09395	09933	10475
1.60	9.9511020	11569	12122	12679	13240	13804	14372	14943	15519	16098
1.61	16680	17267	17857	18451	19048	19650	20254	20862	21475	22091
1.62	22710	23333	23960	24591	25225	25863	26504	27149	27798	28451
1.63	29107	29767	30430	31097	31767	32442	33120	33801	34486	35175
1.64	35867	36563	37263	37966	38673	39383	40097	40815	41536	42260
1.65	9.9542989	43721	44456	45195	45938	46684	47434	48187	48944	49704
1.66	50468	51236	52007	52782	53560	54342	55127	55916	56708	57504
1.67	58303	59106	59913	60723	61536	62353	63174	63998	64826	65656
1.68	66491	67329	68170	69015	69864	70716	71571	72430	73293	74159
1.69	75028	75901	76777	77657	78540	79427	80317	81211	82108	83008
1.70	9.9583912	84820	85731	86645	87536	88484	89409	90337	91268	92203
1.71	93141	94083	95028	95977	96929	97884	98843	99805	00771	01740
1.72	602712	03688	04667	05650	06636	07625	08618	09614	10613	11616
1.73	12622	13632	14645	15661	16681	17704	18730	19760	20793	21830
1.74	22869	23912	24959	26009	27062	28118	29178	30241	31308	32377
1.75	9.9633451	34527	35607	36690	37776	38866	39959	41055	42155	43258
1.76	44364	45473	46586	47702	48821	49944	51070	52200	53331	54467
1.77	55606	56749	57894	59043	60195	61350	62509	63671	64836	66004
1.78	67176	68351	69529	70710	71895	73082	74274	75468	76665	77866
1.79	79070	80277	81488	82701	83198	85138	86361	87588	88818	90051
1.80	9.9691287	92526	93768	95014	96263	97515	98770	00029	01291	02555
1.81	703823	05095	06369	07646	08927	10211	11498	12788	14082	15378
1.82	16678	17981	19287	20596	21908	23224	24542	25864	27189	28517
1.83	29848	31182	32520	33860	35204	36551	37900	39254	40610	41969
1.84	43331	44697	46065	47437	48812	50190	51571	52955	54342	55733
1.85	9.9757126	58522	59922	61325	62730	64140	65551	66966	68384	69805
1.86	71230	72657	74087	75521	76957	78397	79839	81285	82734	84186
1.87	85640	87098	88559	90023	91490	92960	94433	95910	97389	98871
1.88	800356	01844	03335	04830	06327	07827	09331	10837	12346	13859
1.89	15374	16893	18414	19939	21466	22996	24530	26066	27606	29148
1.90	9.9830693	32242	33793	35348	36905	38465	40028	41595	43164	44736
1.91	46311	47890	49471	51055	52642	54232	55825	57421	59020	60622
1.92	62226	63834	65445	67058	68675	70294	71917	73542	75170	76802
1.93	78436	80073	81713	83356	85002	86651	88302	89957	91614	93275
1.94	94938	96605	98274	99946	01621	03299	04980	06663	08350	10039
1.95	9.9911732	13427	15125	16826	18530	20237	21947	23659	25375	27093
1.96	28815	30539	32266	33995	35728	37464	39202	40943	42688	44435
1.97	46185	47937	49693	51451	53213	54977	56744	58513	60286	62062
1.98	63840	65621	67405	69192	70982	72774	74570	76368	78169	79972
1.99	81779	83588	85401	87216	89034	90854	92678	94504	96333	98165

TABLE 31.

ZONAL HARMONICS.*

The values of the first seven zonal harmonics are here given for every degree between $\theta = 0°$ and $\theta = 90°$.

θ	Z_1	Z_2	Z_3	Z_4	Z_5	Z_6	Z_7
0°	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1°	0.9998	0.9995	0.9991	0.9985	0.9977	0.9967	0.9955
2	.9994	.9982	.9963	.9939	.9909	.9872	.9829
3	.9986	.9959	.9918	.9863	.9795	.9713	.9617
4	.9976	.9927	.9854	.9758	.9638	.9495	.9329
5	.9962	.9886	.9773	.9623	.9437	.9216	.8961
6°	.9945	.9836	.9674	.9459	.9194	.8881	.8522
7	.9925	.9777	.9557	.9267	.8911	.8476	.7986
8	.9903	.9709	.9423	.9048	.8589	.8053	.7448
9	.9877	.9633	.9273	.8803	.8232	.7571	.6831
10	.9848	.9548	.9106	.8532	.7840	.7045	.6164
11°	.9816	.9454	.8923	.8238	.7417	.6483	.5461
12	.9781	.9352	.8724	.7920	.6966	.5892	.4732
13	.9744	.9241	.8511	.7582	.6489	.5273	.3940
14	.9703	.9122	.8283	.7224	.5990	.4635	.3219
15	.9659	.8995	.8042	.6847	.5471	.3982	.2454
16°	.9613	.8860	.7787	.6454	.4937	.3322	.1699
17	.9563	.8718	.7519	.6046	.4391	.2660	.0961
18	.9511	.8568	.7240	.5624	.3836	.2002	.0289
19	.9455	.8410	.6950	.5192	.3276	.1347	—.0443
20	.9397	.8245	.6649	.4750	.2715	.0719	—.1072
21°	.9336	.8074	.6338	.4300	.2156	.0107	—.1662
22	.9272	.7895	.6019	.3845	.1602	—.0481	—.2201
23	.9205	.7710	.5692	.3386	.1057	—.1038	—.2681
24	.9135	.7518	.5357	.2926	.0525	—.1559	—.3095
25	.9063	.7321	.5016	.2465	.0009	—.2053	—.3463
26°	.8988	.7117	.4670	.2007	—.0489	—.2478	—.3717
27	.8910	.6908	.4319	.1553	—.0964	—.2869	—.3921
28	.8829	.6694	.3964	.1105	—.1415	—.3211	—.4052
29	.8746	.6474	.3607	.0665	—.1839	—.3503	—.4114
30	.8660	.6250	.3248	.0234	—.2233	—.3740	—.4101
31°	.8572	.6021	.2887	—.0185	—.2595	—.3924	—.4022
32	.8480	.5788	.2527	—.0591	—.2923	—.4052	—.3876
33	.8387	.5551	.2167	—.0982	—.3216	—.4126	—.3670
34	.8290	.5310	.1809	—.1357	—.3473	—.4148	—.3409
35	.8192	.5065	.1454	—.1714	—.3691	—.4115	—.3096
36°	.8090	.4818	.1102	—.2052	—.3871	—.4031	—.2738
37	.7986	.4567	.0755	—.2370	—.4011	—.3898	—.2343
38	.7880	.4314	.0413	—.2666	—.4112	—.3719	—.1918
39	.7771	.4059	.0077	—.2940	—.4174	—.3497	—.1469
40	.7660	.3802	—.0252	—.3190	—.4197	—.3234	—.1003
41°	.7547	.3544	—.0574	—.3416	—.4181	—.2938	—.0534
42	.7431	.3284	—.0887	—.3616	—.4128	—.2611	—.0065
43	.7314	.3023	—.1191	—.3791	—.4038	—.2255	.0395
44	.7193	.2762	—.1485	—.3940	—.3914	—.1878	.0846
45	.7071	.2500	—.1768	—.4062	—.3757	—.1485	.1270

* Calculated by Prof. Perry (Phil. Mag. Dec. 1891). See also A. Gray, "Absolute Measurements in Electricit and Magnetism," vol. ii., part 2.

ZONAL HARMONICS.

θ	z_1	z_2	z_3	z_4	z_5	z_6	z_7
46°	0.6947	0.2238	—.2040	—.4158	—.3568	—.1079	0.1666
47	.6820	.1977	—.2300	—.4252	—.3350	—.0645	.2054
48	.6691	.1716	—.2547	—.4270	—.3105	—.0251	.2349
49	.6561	.1456	—.2781	—.4286	—.2836	.0161	.2627
50	.6428	.1198	—.3002	—.4275	—.2545	.0563	.2854
51°	.6293	.0941	—.3209	—.4239	—.2235	.0954	.3031
52	.6157	.0686	—.3401	—.4178	—.1910	.1326	.3153
53	.6018	.0433	—.3578	—.4093	—.1571	.1677	.3221
54	.5878	.0182	—.3740	—.3984	—.1223	.2002	.3234
55	.5736	—.0065	—.3886	—.3852	—.0868	.2297	.3191
56°	.5592	—.0310	—.4016	—.3698	—.0510	.2559	.3095
57	.5446	—.0551	—.4131	—.3524	—.0150	.2787	.2949
58	.5299	—.0788	—.4229	—.3331	.0206	.2976	.2752
59	.5150	—.1021	—.4310	—.3119	.0557	.3125	.2511
60	.5000	—.1250	—.4375	—.2891	.0898	.3232	.2231
61°	.4848	—.1474	—.4423	—.2647	.1229	.3298	.1916
62	.4695	—.1694	—.4455	—.2390	.1545	.3321	.1571
63	.4540	—.1908	—.4471	—.2121	.1844	.3302	.1203
64	.4384	—.2117	—.4470	—.1841	.2123	.3240	.0818
65	.4226	—.2321	—.4452	—.1552	.2381	.3138	.0422
66°	.4067	—.2518	—.4419	—.1256	.2615	.2996	.0021
67	.3907	—.2710	—.4370	—.0955	.2824	.2819	—.0375
68	.3746	—.2896	—.4305	—.0650	.3005	.2605	—.0763
69	.3584	—.3074	—.4225	—.0344	.3158	.2361	—.1135
70	.3420	—.3245	—.4130	—.0038	.3281	.2089	—.1485
71°	.3256	—.3410	—.4021	.0267	.3373	.1786	—.1811
72	.3090	—.3568	—.3898	.0568	.3434	.1472	—.2099
73	.2924	—.3718	—.3761	.0864	.3463	.1144	—.2347
74	.2756	—.3860	—.3611	.1153	.3461	.0795	—.2559
75	.2588	—.3995	—.3449	.1434	.3427	.0431	—.2730
76°	.2419	—.4112	—.3275	.1705	.3362	.0076	—.2848
77	.2250	—.4241	—.3090	.1964	.3267	—.0284	—.2919
78	.2079	—.4352	—.2894	.2211	.3143	—.0644	—.2943
79	.1908	—.4454	—.2688	.2443	.2990	—.0989	—.2913
80	.1736	—.4548	—.2474	.2659	.2810	—.1321	—.2835
81°	.1564	—.4633	—.2251	.2859	.2606	—.1635	—.2709
82	.1392	—.4709	—.2020	.3040	.2378	—.1926	—.2536
83	.1219	—.4777	—.1783	.3203	.2129	—.2193	—.2321
84	.1045	—.4836	—.1539	.3345	.1861	—.2431	—.2067
85	.0872	—.4886	—.1291	.3468	.1577	—.2638	—.1779
86°	.0698	—.4927	—.1038	.3569	.1278	—.2811	—.1460
87	.0523	—.4959	—.0781	.3648	.0969	—.2947	—.1117
88	.0349	—.4982	—.0522	.3704	.0651	—.3045	—.0735
89	.0175	—.4995	—.0262	.3739	.0327	—.3105	—.0381
90	.0000	—.5000	—.0000	.3750	.0000	—.3125	—.0000

MUTUAL INDUCTANCE.*

Values of $\log \frac{M}{4\pi\sqrt{aa'}}$.

Table of values of $\log \frac{M}{4\pi\sqrt{aa'}}$ for facilitating the calculation of the mutual inductance M of two coaxial circles of radii a, a', at distance apart δ. The table is calculated for intervals of $6'$ in the value of $\cos^{-1}\left\{\frac{(a-a')^2+\delta^2}{(a-a')^2+\delta^2}\right\}^{\frac{1}{2}}$ from 60° to 90°.

	0′	6′	12′	18′	24′	30′	36′	42′	48′	54′
60°	$\bar{1}$.4994783	5022651	5050505	5078345	5106173	5133989	5161791	5189582	5217361	5245128
61	5272883	5300628	5328361	5356084	5383796	5411498	5439190	5466872	5494545	5522209
62	5549864	5577510	5605147	5632776	5660398	5688011	5715618	5743217	5770809	5798394
63	5825973	5853546	5881113	5908675	5936231	5963782	5991322	6018871	6046408	6073942
64	6101472	6128998	6156522	6184042	6211560	6239076	6266589	6294101	6321612	6349121
65°	$\bar{1}$.6376629	6404137	6431645	6459153	6486660	6514169	6541678	6569189	6596701	6624215
66	6651732	6679250	6706772	6734296	6761824	6789356	6816891	6844431	6871976	6899526
67	6927081	6954642	6982209	7009782	7037362	7064949	7092544	7120146	7147756	7175375
68	7203003	7230640	7258286	7285942	7313609	7341287	7368975	7396675	7424387	7452111
69	7479848	7507597	7535361	7563138	7590929	7618735	7646556	7674392	7702245	7730114
70°	$\bar{1}$.7758000	7785903	7813823	7841762	7869720	7897696	7925692	7953709	7981745	8009803
71	8037882	8065983	8094107	8122253	8150423	8178617	8206836	8235080	8263349	8291645
72	8319967	8348316	8376693	8405099	8433534	8461998	8490493	8519018	8547575	8576164
73	8604785	8633440	8662129	8690852	8719611	8748406	8777237	8806106	8835013	8863958
74	8892943	8921969	8951036	8980144	9009295	9038489	9067728	9097012	9126341	9155717
75°	$\bar{1}$.9185141	9214613	9244135	9273707	9303330	9333005	9362733	9392515	9422352	9452246
76	9482196	9512205	9542272	9572400	9602590	9632841	9663157	9693537	9723983	9754497
77	9785079	9815731	9846454	9877249	9908118	9939062	9970082	$\bar{0}$001181	$\bar{0}$032359	$\bar{0}$063618
78	0.0094959	0126385	0157896	0189494	0221181	0252959	0284830	0316794	0348855	0381014
79	0413273	0445633	0478098	0510668	0543347	0576136	0609037	0642054	0675187	0708441
80°	0.0741816	0775316	0808944	0842702	0876592	0910619	0944784	0979091	1013542	1048142
81	1082893	1117799	1152863	1188089	1223481	1259043	1294778	1330691	1366786	1403067
82	1439539	1476207	1513075	1550149	1587434	1624935	1662658	1700609	1738794	1777219
83	1815890	1854815	1894001	1933455	1973184	2013197	2053502	2094108	2135026	2176259
84	2217823	2259728	2301983	2344600	2387591	2430970	2474748	2518940	2563561	2608626
85°	0.2654152	2700156	2746655	2793670	2841221	2889329	2938018	2987312	3037238	3087823
86	3139097	3191092	3243843	3297387	3351762	3407012	3463184	3520327	3578495	3637749
87	3698153	3759777	3822700	3887006	3952792	4020162	4089234	4160138	4233022	4308053
88	4385420	4465341	4548064	4633880	4723127	4816206	4913595	5015870	5123738	5238079
89	5360007	5490969	5632886	5788406	5961320	6157370	6385907	6663883	7027765	7586941

* Quoted from Gray's "Absolute Measurements in Electricity and Magnetism," vol. ii., p. 852.

ELLIPTIC INTEGRALS.

Values of $\int_0^{\frac{\pi}{2}} (1-\sin^2\theta\sin^2\phi)^{\pm\frac{1}{2}}\,d\phi$.

This table gives the values of the integrals between 0 and $\pi/2$ of the function $(1-\sin^2\theta\sin^2\phi)^{\pm\frac{1}{2}}\,d\phi$ for different values of the modulus corresponding to each degree of θ between 0 and 90.

θ	$\int_0^{\frac{\pi}{2}} \frac{d\phi}{(1-\sin^2\theta\sin^2\phi)^{\frac{1}{2}}}$		$\int_0^{\frac{\pi}{2}} (1-\sin^2\theta\sin^2\phi)^{\frac{1}{2}}\,d\phi$		θ	$\int_0^{\frac{\pi}{2}} \frac{d\phi}{(1-\sin^2\theta\sin^2\phi)^{\frac{1}{2}}}$		$\int_0^{\frac{\pi}{2}} (1-\sin^2\theta\sin^2\phi)^{\frac{1}{2}}\,d\phi$	
	Number.	Log.	Number.	Log.		Number.	Log.	Number.	Log.
0°	1.5708	0.196120	1.5708	0.196120	45°	1.8541	0.268127	1.3506	0.130541
1	5709	196153	5707	196087	6	8691	271644	3418	127690
2	5713	196252	5703	195988	7	8848	275267	3329	124788
3	5719	196418	5697	195822	8	9011	279001	3238	121836
4	5727	196649	5689	195591	9	9180	282848	3147	118836
5°	1.5738	0.196947	1.5678	0.195293	50°	1.9356	0.286811	1.3055	0.115790
6	5751	197312	5665	194930	1	9539	290895	2963	112698
7	5767	197743	5649	194500	2	9729	295101	2870	109563
8	5785	198241	5632	194004	3	9927	299435	2776	106386
9	5805	198806	5611	193442	4	2.0133	303901	2681	103169
10°	1.5828	0.199438	1.5589	0.192815	55°	2.0347	0.308504	1.2587	0.099915
1	5854	200137	5564	192121	6	0571	313247	2492	096626
2	5882	200904	5537	191362	7	0804	318138	2397	093303
3	5913	201740	5507	190537	8	1047	323182	2301	089950
4	5946	202643	5476	189646	9	1300	328384	2206	086569
15°	1.5981	0.203615	1.5442	0.188690	60°	2.1565	0.333753	1.2111	0.083164
6	6020	204657	5405	187668	1	1842	339295	2015	079738
7	6061	205768	5367	186581	2	2132	345020	1920	076293
8	6105	206948	5326	185428	3	2435	350936	1826	072834
9	6151	208200	5283	184210	4	2754	357053	1732	069364
20°	1.6200	0.209522	1.5238	0.182928	65°	2.3088	0.363384	1.1638	0.065889
1	6252	210916	5191	181580	6	3439	369940	1545	062412
2	6307	212382	5141	180168	7	3809	376736	1453	058937
3	6365	213921	5090	178691	8	4198	383787	1362	055472
4	6426	215533	5037	177150	9	4610	391112	1272	052020
25°	1.6490	0.217219	1.4981	0.175545	70°	2.5046	0.398730	1.1184	0.048589
6	6557	218981	4924	173876	1	5507	406665	1096	045183
7	6627	220818	4864	172144	2	5998	414943	1011	041812
8	6701	222732	4803	170348	3	6521	423596	0927	038481
9	6777	224723	4740	168489	4	7081	432660	0844	035200
30°	1.6858	0.226793	1.4675	0.166567	75°	2.7681	0.442176	1.0764	0.031976
1	6941	228943	4608	164583	6	8327	452196	0686	028819
2	7028	231173	4539	162537	7	9026	462782	0611	025740
3	7119	233485	4469	160429	8	9786	474008	0538	022749
4	7214	235880	4397	158261	9	3.0617	485967	0468	019858
35°	1.7312	0.238359	1.4323	0.156031	80°	3.1534	0.498777	1.0401	0.017081
6	7415	240923	4248	153742	1	2553	512591	0338	014432
7	7522	243575	4171	151393	2	3699	527613	0278	011927
8	7633	246315	4092	148985	3	5004	544120	0223	009584
9	7748	249146	4013	146519	4	6519	562514	0172	007422
40°	1.7868	0.252068	1.3931	0.143995	85°	3.8317	0.583396	1.0127	0.005465
1	7992	255085	3849	141414	6	4.0528	607751	0086	003740
2	8122	258197	3765	138778	7	3387	637355	0053	002278
3	8256	261406	3680	136086	8	7427	676027	0026	001121
4	8396	264716	3594	133340	9	5.4349	735192	0008	000326
45°	1.8541	0.268127	1.3506	0.130541	90°	∞	∞	1.0000	———

MOMENTS OF INERTIA, RADII OF GYRATION, AND WEIGHTS.

In each case the axis is supposed to traverse the centre of gravity of the body. The axis is one of symmetry. The mass of a unit of volume is w.

Body.	Axis.	Weight.	Moment of Inertia I_o.	Square of Radius of Gyration ρ_o^2.
Sphere of radius r	Diameter	$\frac{4\pi w r^3}{3}$	$\frac{8\pi w r^5}{15}$	$\frac{2r^2}{5}$
Spheroid of revolution, polar axis $2a$, equatorial diameter $2r$	Polar axis	$\frac{4\pi w a r^2}{3}$	$\frac{8\pi w a r^4}{15}$	$\frac{2r^2}{5}$
Ellipsoid, axes $2a$, $2b$, $2c$	Axis $2a$	$\frac{4\pi w a b c}{3}$	$\frac{4\pi w a b c(b^2+c^2)}{15}$	$\frac{b^2+c^2}{5}$
Spherical shell, external radius r, internal r'	Diameter	$\frac{4\pi w(r^3-r'^3)}{3}$	$\frac{8\pi w(r^5-r'^5)}{15}$	$\frac{2(r^5-r'^5)}{5(r^3-r'^3)}$
Ditto, insensibly thin, radius r, thickness dr	Diameter	$4\pi w r^2 dr$	$\frac{8\pi w r^4 dr}{3}$	$\frac{2r^2}{3}$
Circular cylinder, length $2a$, radius r	Longitudinal axis $2a$	$2\pi w a r^2$	$\pi w a r^4$	$\frac{r^2}{2}$
Elliptic cylinder, length $2a$, transverse axes $2b$, $2c$	Longitudinal axis $2a$	$2\pi w a b c$	$\frac{\pi w a b c(b^2+c^2)}{2}$	$\frac{b^2+c^2}{4}$
Hollow circular cylinder, length $2a$, external radius r, internal r'	Longitudinal axis $2a$	$2\pi w a(r^2-r'^2)$	$\pi w a(r^4-r'^4)$	$\frac{r^2+r'^2}{2}$
Ditto, insensibly thin, thickness dr	Longitudinal axis $2a$	$4\pi w a r dr$	$4\pi w a r^3 dr$	r^2
Circular cylinder, length $2a$, radius r	Transverse diameter	$2\pi w a r^2$	$\frac{\pi w a r^2(3r^2+4a^2)}{6}$	$\frac{r^2}{4}+\frac{a^2}{3}$
Elliptic cylinder, length $2a$, transverse axes $2a$, $2b$	Transverse axis $2b$	$2\pi w a b c$	$\frac{\pi w a b c(3c^2+4a^2)}{6}$	$\frac{c^2}{4}+\frac{a^2}{3}$
Hollow circular cylinder, length $2a$, external radius r, internal r'	Transverse diameter	$2\pi w a(r^2-r'^2)$	$\frac{\pi w a}{6}\{3(r^4-r'^4)+4a^2(r^2-r'^2)\}$	$\frac{r^2+r'^2}{4}+\frac{a^2}{3}$
Ditto, insensibly thin, thickness dr	Transverse diameter	$4\pi w a r dr$	$\pi w a(2r^3+\frac{4}{3}a^2 r)dr$	$\frac{r^2}{2}+\frac{a^2}{3}$
Rectangular prism, dimensions $2a$, $2b$, $2c$	Axis $2a$	$8wabc$	$\frac{8wabc(b^2+c^2)}{3}$	$\frac{b^2+c^2}{3}$
Rhombic prism, length $2a$, diagonals $2b$, $2c$	Axis $2a$	$4wabc$	$\frac{2wabc(b^2+c^2)}{3}$	$\frac{b^2+c^2}{6}$
Ditto	Diagonal $2b$	$4wabc$	$\frac{2wabc(c^2+2a^2)}{3}$	$\frac{c^2}{6}+\frac{a^2}{3}$

(Taken from Rankine.)

BRITISH GAUGE NUMBERS AND SIZES OF WIRES.

For Brown & Sharp American Gauge and Electrical Constants see Tables 40 and 41.

TABLE 35.—British Standard Wire Gauge.

Gauge Number	Diameter in Inches.	Section in Sq. Inches.	Diameter in Centimetres.	Section in Sq. Cms.
7-0	0.500	0.1963	1.2700	1.267
6-0	.464	.1691	.1786	.091
5-0	0.432	0.1466	1.0973	0.9456
4-0	.400	.1257	.0160	.8107
3-0	.372	.1087	0.9449	.7012
2-0	.348	.0951	.8839	.6136
0	.324	.0825	.8230	.5319
1	0.300	0.07069	0.7620	0.4560
2	.276	.05983	.7010	.3858
3	.252	.04988	.6401	.3218
4	.232	.04227	.5893	.2727
5	.212	.03530	.5385	.2277
6	0.192	0.02895	0.4877	0.18679
7	.176	.02433	.4470	.15696
8	.160	.02010	.4064	.12973
9	.144	.01629	.3658	.10507
10	.128	.01287	.3251	.08302
11	0.116	0.010568	0.2946	0.06818
12	.104	.008495	.2642	.05480
13	.092	.006648	.2337	.04289
14	.080	.005027	.2032	.03243
15	.072	.004071	.1829	.02627
16	0.064	0.003217	0.16256	0.020755
17	.056	.002463	.14224	.015890
18	.048	.001810	.12192	.011675
19	.040	.001257	.10160	.008107
20	.036	.001018	.09144	.006567
21	0.032	0.0008042	0.08128	0.005189
22	.028	.0006158	.07112	.003973
23	.024	.0004524	.06096	.002922
24	.022	.0003801	.05588	.002452
25	.020	.0003142	.05080	.002027
26	0.0180	0.0002545	0.04572	0.0016417
27	.0164	.0002112	.04166	.0013628
28	.0148	.0001728	.03759	.0011099
29	.0136	.0001453	.03454	.0009363
30	.0124	.0001208	.03150	.0007791
31	0.0116	0.00010568	0.02946	0.0006818
32	.0108	.00009161	.02743	.0005910
33	.0100	.00007854	.02540	.0005067
34	.0092	.00006648	.02337	.0004289
35	.0084	.00005542	.02134	.0003575
36	0.0076	0.00004536	0.01930	0.0002927
37	.0068	.00003632	.01727	.0002343
38	.0060	.00002827	.01524	.0001824
39	.0052	.00002124	.01321	.0001370
40	.0048	.00001810	.01219	.0001167
41	0.0044	0.00001521	0.01118	0.0000982
42	.0040	.00001257	.01016	.0000811
43	.0036	.00001018	.00914	.0000656
44	.0032	.00000804	.00813	.0000519
45	.0028	.00000616	.00711	.0000397
46	0.0024	0.00000452	0.00610	0.0000292
47	.0020	.00000314	.00508	.0000203
48	.0016	.00000201	.00406	.0000129
49	.0012	.00000113	.00305	.0000073
50	.0010	.00000079	.00254	.0000051

TABLE 36.—Birmingham Wire Gauge.

Gauge Number.	Diameter in Inches.	Sections in Sq. Inches.	Diameter in Centimetres.	Section in Sq. Cms.
0000	0.454	0.16188	1.1532	1.0444
000	.425	.14186	.0795	.9152
00	.380	.11341	0.9652	.7317
0	.340	.09079	.8636	.5858
1	0.300	0.07069	0.7620	0.4560
2	.284	.06335	.7214	.4087
3	.259	.05269	.6579	.3399
4	.238	.04449	.6045	.2870
5	.220	.03801	.5588	.2452
6	0.203	0.03237	0.5156	0.20881
7	.180	.02545	.4572	.16417
8	.165	.02138	.4191	.13795
9	.148	.01720	.3759	.11099
10	.134	.01410	.3404	.09098
11	0.120	0.011310	0.3048	0.07297
12	.109	.009331	.2769	.06160
13	.095	.007088	.2413	.04573
14	.083	.005411	.2108	.03491
15	.072	.004072	.1829	.02627
16	0.065	0.0033183	0.16510	0.021409
17	.058	.0026421	.14732	.017046
18	.049	.0018857	.12446	.012166
19	.042	.0013854	.10668	.008938
20	.035	.0009621	.08890	.006207
21	0.032	0.0008042	0.08128	0.005189
22	.028	.0006158	.07112	.003973
23	.025	.0004909	.06350	.003167
24	.022	.0003801	.05588	.002452
25	.020	.0003142	.05080	.002027
26	0.018	0.0002545	0.04572	0.0016417
27	.016	.0002011	.04064	.0012972
28	.014	.0001539	.03556	.0009932
29	.013	.0001327	.03302	.0008563
30	.012	.0001181	.03048	.0007297
31	0.010	0.00007854	0.02540	0.0005067
32	.009	.00006362	.02286	.0004104
33	.008	.00005027	.02032	.0003243
34	.007	.00003848	.01778	.0002483
35	.005	.00001963	.01270	.0001267
36	0.004	0.00001257	0.01016	0.0000811

TABLE 29.
DIFFUSION.

Inverse* values of $v/c = 1 - \frac{2}{\sqrt{\pi}} \int_0^q e^{-q^2} dq$.

$\log x = \log(2q) + \log\sqrt{kt}$. t expressed in seconds.

$= \log\delta + \log\sqrt{kt}$. t expressed in days.

$= \log\gamma + \log\sqrt{kt}$. " " years.

k = coefficient of diffusion.†

c = initial concentration.

v = concentration at distance x, time t.

v/c	$\log 2q$	$2q$	$\log\delta$	δ	$\log\gamma$	γ
0.00	$+\infty$	$+\infty$	$+\infty$	$+\infty$	∞	∞
.01	0.56143	3.6428	3.02970	1070.78	4.31098	20463.
.02	.51719	3.2900	2.98545	967.04	.26674	18481.
.03	.48699	3.0690	.95525	902.90	.23654	17240.
.04	.46306	2.9044	.93132	853.73	.21261	16316.
0.05	0.44276	2.7718	2.91102	814.74	4.19231	15571.
.06	.42486	2.6598	.89311	781.83	.17440	14942.
.07	.40865	2.5624	.87691	753.20	.15820	14395.
.08	.39372	2.4758	.86198	727.75	.14327	13908.
.09	.37979	2.3977	.84804	704.76	.12933	13469.
0.10	0.36664	2.3262	2.83490	683.75	4.11619	13067.
.11	.35414	2.2602	.82240	664.36	.10369	12697.
.12	.34218	2.1988	.81044	646.31	.09173	12352.
.13	.33067	2.1413	.79893	629.40	.08022	12029.
.14	.31954	2.0871	.78780	613.47	.06909	11724.
0.15	0.30874	2.0358	2.77699	598.40	4.05828	11436.
.16	.29821	1.9871	.76647	584.08	.04776	11162.
.17	.28793	1.9406	.75619	570.41	.03748	10901.
.18	.27786	1.8961	.74612	557.34	.02741	10652.
.19	.26798	1.8534	.73624	544.80	.01753	10412.
0.20	0.25825	1.8124	2.72651	532.73	4.00780	10181.
.21	.24866	1.7728	.71692	521.10	3.99821	9958.9
.22	.23919	1.7346	.70745	509.86	.98874	9744.1
.23	.22983	1.6976	.69808	498.98	.97937	9536.2
.24	.22055	1.6617	.68880	488.43	.97010	9334.6
0.25	0.21134	1.6268	2.67960	478.19	3.96089	9138.9
.26	.20220	1.5930	.67046	468.23	.95175	8948.5
.27	.19312	1.5600	.66137	458.53	.94266	8763.2
.28	.18407	1.5278	.65232	449.08	.93361	8582.5
.29	.17505	1.4964	.64331	439.85	.92460	8406.2
0.30	0.16606	1.4657	2.63431	430.84	3.91560	8233.9
.31	.15708	1.4357	.62533	422.02	.90662	8065.4
.32	.14810	1.4064	.61636	413.39	.89765	7900.4
.33	.13912	1.3776	.60738	404.93	.88867	7738.8
.34	.13014	1.3494	.59840	396.64	.87969	7580.3
0.35	0.12114	1.3217	2.58939	388.50	3.87068	7424.8
.36	.11211	1.2945	.58037	380.51	.86166	7272.0
.37	.10305	1.2678	.57131	372.66	.85260	7122.0
.38	.09396	1.2415	.56222	364.93	.84351	6974.4
.39	.08482	1.2157	.55308	357.34	.83437	6829.2
0.40	0.07563	1.1902	2.54389	349.86	3.82518	6686.2
.41	.06639	1.1652	.53464	342.49	.81593	6545.4
.42	.05708	1.1405	.52533	335.22	.80662	6406.6
.43	.04770	1.1161	.51595	328.06	.79724	6269.7
.44	.03824	1.0920	.50650	320.99	.78779	6134.6
0.45	0.02870	1.0683	2.49696	314.02	3.77825	6001.3
.46	.01907	1.0449	.48733	307.13	.76862	5869.7
.47	.00934	1.0217	.47760	300.33	.75889	5739.7
.48	9.99951	0.99886	.46776	293.60	.74905	5611.2
.49	.98956	0.97624	.45782	286.96	.73911	5484.1
0.50	9.97949	0.95387	2.44775	280.38	3.72904	5358.4

* Kelvin, Mathematical and Physical Papers, vol. III. p. 428; Becker, Am. Jour. of Sci. vol. III. 1897, p. 280.

† For direct values see table 23.

Taken from unpublished manuscript of C. E. Van Orstrand.

BRITISH UNITS.

Cross sections and weights of wires.

Diam. in Mils.	Area of cross section in Sq. Mils.	Copper — Density 8.90.			Iron — Density 7.80.			Brass — Density 8.56.		
		Pounds per Foot.	Log.	Feet per Pound.	Pounds per Foot.	Log.	Feet per Pound.	Pounds per Foot.	Log.	Feet per Pound.
55	2375.83	.009167	$\bar{3}$.96223	109.1	.008034	$\bar{3}$.90493	124.5	.008817	$\bar{3}$.94531	113.4
56	2463.01	09504	.97789	105.2	08329	.92058	120.1	09140	.96096	109.4
57	2551.76	09846	.99325	101.6	08629	.93595	115.9	09470	.97633	105.6
58	2642.08	10195	$\bar{2}$.00837	98.1	08934	.95106	111.9	09805	.99144	102.0
59	2733.97	10549	.02320	94.8	09245	.96591	108.2	10146	$\bar{2}$.00629	98.6
60	2827.43	.01091	$\bar{2}$.03782	91.66	.00956	$\bar{3}$.98050	104.59	.01049	$\bar{2}$.02088	95.30
61	2922.47	1128	.05216	88.68	0988	.99486	101.19	1085	.03524	92.21
62	3019.07	1165	.06628	85.84	1021	$\bar{2}$.00898	97.95	1120	.04936	89.25
63	3117.25	1203	.08019	83.14	1054	.02288	94.87	1157	.06326	86.45
64	3216.99	1241	.09386	80.56	1088	.03656	91.83	1194	.07694	83.77
65	3318.31	.01280	$\bar{2}$.10732	78.11	.01122	$\bar{2}$.05003	89.12	.01231	$\bar{2}$.09041	81.21
66	3421.19	1320	.12061	75.76	1157	.06329	86.44	1270	.10367	78.76
67	3525.65	1360	.13367	73.51	1192	.07635	83.88	1308	.11673	76.43
68	3631.68	1401	.14655	71.36	1228	.08922	81.42	1348	.12960	74.20
69	3739.28	1443	.15924	69.30	1264	.10190	79.09	1388	.14228	72.06
70	3848.45	.01485	$\bar{2}$.17174	67.34	.01302	$\bar{2}$.11451	76.82	.01429	$\bar{2}$.15489	70.00
71	3959.19	1528	.18404	65.46	1339	.12672	74.69	1469	.16710	68.06
72	4071.50	1571	.19618	63.65	1377	.13887	72.63	1511	.17925	66.19
73	4185.39	1615	.20817	61.92	1415	.15085	70.66	1553	.19123	64.38
74	4300.84	1660	.22000	60.26	1454	.16267	68.76	1596	.20304	62.66
75	4417.86	.01705	$\bar{2}$.23165	58.66	.01494	$\bar{2}$.17432	66.95	.01639	$\bar{2}$.21460	61.01
76	4536.46	1751	.24317	57.13	1534	.18583	65.19	1684	.22621	59.40
77	4656.63	1797	.25453	55.65	1575	.19718	63.50	1728	.23756	57.87
78	4778.36	1844	.26574	54.23	1616	.20839	61.89	1773	.24877	56.39
79	4901.67	1892	.27681	52.87	1658	.21946	60.33	1819	.25974	54.99
80	5026.55	.01939	$\bar{2}$.28769	51.56	.01700	$\bar{2}$.23038	58.83	.01865	$\bar{2}$.27076	53.61
81	5153.00	1988	.29848	50.29	1743	.24117	57.39	1912	.28155	52.29
82	5281.02	2038	.30914	49.07	1786	.25183	56.00	1960	.29221	51.03
83	5410.61	2088	.31966	47.90	1830	.26236	54.66	2008	.30274	49.80
84	5541.77	2138	.33006	46.77	1874	.27276	53.36	2057	.31314	48.63
85	5674.50	.02189	$\bar{2}$.34034	45.67	.01919	$\bar{2}$.28304	52.11	.02106	$\bar{2}$.32342	47.49
86	5808.80	2241	.35050	44.62	1964	.29320	50.91	2156	.33358	46.39
87	5944.68	2294	.36054	43.60	2010	.30324	49.75	2206	.34362	45.33
88	6082.12	2347	.37047	42.61	2057	.31317	48.62	2257	.35355	44.30
89	6221.14	2400	.38028	41.66	2104	.32298	47.54	2309	.36336	43.31
90	6361.73	.02455	$\bar{2}$.38999	40.74	.02151	$\bar{2}$.33269	46.49	.02360	$\bar{2}$.37297	42.37
91	6503.88	2509	.39958	39.85	2199	.34228	45.47	2414	.38266	41.43
92	6647.61	2565	.40908	38.99	2248	.35178	44.49	2467	.39216	40.54
93	6792.91	2621	.41847	38.15	2297	.36116	43.54	2521	.40154	39.67
94	6939.78	2678	.42775	37.35	2347	.37046	42.61	2575	.41084	38.83
95	7088.22	.02735	$\bar{2}$.43694	36.56	.02397	$\bar{2}$.37965	41.72	.02630	$\bar{2}$.42003	38.02
96	7238.23	2793	.44604	35.81	2448	.38874	40.86	2686	.42912	37.23
97	7389.81	2851	.45504	35.07	2499	.39775	40.02	2742	.43812	36.46
98	7542.96	2910	.46395	34.36	2551	.40665	39.20	2799	.44703	35.72
99	7697.69	2970	.47277	33.67	2603	.41547	38.42	2857	.45585	35.01
100	7853.98	.03030	$\bar{2}$.48150	33.00	.02656	$\bar{2}$.42420	37.65	.02915	$\bar{2}$.46458	34.31

METRIC UNITS.

Cross sections and weights of wires.

This table gives the cross section and the weight in metric units of copper, iron, and brass wires of the diameters given in the first column. For one tenth the diameter divide sections and weights by 100. For ten times the diameter multiply by 100, and so on.

Diam. in thousandths of a cm.	Area of cross section $(\frac{1}{1000})^2$	Copper — Density 8.90.			Iron — Density 7.80.			Brass — Density 8.56.		
		Grammes per Metre.	Log.	Metres per Gramme.	Grammes per Metre.	Log.	Metres per Gramme.	Grammes per Metre.	Log.	Metres per Gramme.
10	78.54	0.06990	$\bar{2}.84448$	14.306	0.06126	$\bar{2}.78718$	16.324	0.06723	$\bar{2}.82756$	14.874
11	95.03	.08458	.92725	11.823	.07412	.86996	13.492	.08135	.91034	12.293
12	113.10	.10065	$\bar{1}.00285$	9.935	.08822	.94556	11.335	.09681	.98594	10.330
13	132.73	.11813	.07236	8.465	.10353	$\bar{1}.01506$	9.659	.11362	$\bar{1}.05544$	8.801
14	153.94	.13701	.13674	7.299	.12008	.07945	8.328	.13177	.11983	7.589
15	176.71	0.1573	$\bar{1}.19665$	6.358	0.1378	$\bar{1}.13936$	7.255	0.1513	$\bar{1}.17974$	6.611
16	201.06	.1789	.25272	5.588	.1568	.19542	6.376	.1721	.23580	5.810
17	226.98	.2020	.30538	4.951	.1770	.24808	5.648	.1943	.28846	5.147
18	254.47	.2265	.35503	4.415	.1985	.29773	5.038	.2178	.33811	4.591
19	283.53	.2523	.40199	3.963	.2212	.34469	4.522	.2427	.38507	4.120
20	314.16	0.2796	$\bar{1}.44654$	3.577	0.2450	$\bar{1}.38925$	4.081	0.2689	$\bar{1}.42963$	3.719
21	346.36	.3083	.48892	.244	.2702	.43162	3.701	.2965	.47200	.373
22	380.13	.3383	.52932	2.956	.2965	.47203	.373	.3254	.51241	.073
23	415.48	.3698	.56794	.704	.3241	.51064	.086	.3557	.55103	2.812
24	452.39	.4026	.60490	.484	.3529	.54761	2.834	.3872	.58799	.582
25	490.87	0.4369	$\bar{1}.64036$	2.289	0.3829	$\bar{1}.58306$	2.612	0.4202	$\bar{1}.62344$	2.380
26	530.93	.4725	.67443	.116	.4141	.61713	.415	.4545	.65751	.200
27	572.56	.5096	.70721	1.962	.4466	.64992	.239	.4901	.69030	.040
28	615.75	.5480	.73880	.825	.4803	.68150	.082	.5271	.72188	1.897
29	660.52	.5879	.76928	.701	.5152	.71198	1.941	.5654	.75236	.769
30	706.86	0.6291	$\bar{1}.79872$	1.590	0.5514	$\bar{1}.74143$	1.814	0.6051	$\bar{1}.78181$	1.653
31	754.77	.6717	.82721	.489	.5887	.76991	.699	.6461	.81029	.548
32	804.25	.7158	.85478	.397	.6273	.79749	.594	.6884	.83787	.453
33	855.30	.7612	.88151	.314	.6671	.82421	.499	.7321	.86459	.366
34	907.92	.8081	.90744	.238	.7082	.85014	.412	.7772	.89052	.287
35	962.11	0.856	$\bar{1}.93261$	1.168	0.7504	$\bar{1}.87531$	1.333	0.8236	$\bar{1}.91570$	1.214
36	1017.88	.906	.95709	.104	.7939	.89979	.260	.8713	.94017	.148
37	1075.21	.957	.98088	.045	.8387	.92359	.192	.9204	.96397	.087
38	1134.11	1.012	0.00504	0.988	.8866	.94775	.128	.9730	.98813	.028
39	1194.59	.063	.02661	.941	.9318	.96931	.073	1.0230	0.00969	0.978
40	1256.64	1.118	0.04861	0.8941	0.980	$\bar{1}.99131$	1.0200	1.076	0.03169	0.9296
41	1320.25	.175	.07005	.8511	1.030	0.01275	0.9711	.130	.05313	.8849
42	1385.44	.233	.09098	.8110	.081	.03368	.9254	.186	.07406	.8432
43	1452.20	.292	.11142	.7738	.133	.05412	.8828	.243	.09450	.8044
44	1520.53	.353	.13139	.7389	.186	.07409	.8432	.302	.11447	.7683
45	1590.43	1.415	0.15091	0.7065	1.241	0.09361	0.8061	1.361	0.13399	0.7345
46	1661.90	.479	.17000	.6761	.296	.11270	.7714	.423	.15308	.7029
47	1734.94	.544	.18868	.6476	.353	.13138	.7389	.485	.17176	.6734
48	1809.56	.611	.20696	.6209	.411	.14967	.7085	.549	.19005	.6456
49	1885.74	.678	.22487	.5958	.471	.16758	.6799	.614	.20796	.6195
50	1963.50	1.748	0.24242	0.5722	1.532	0.18513	0.6530	1.681	0.22551	0.5950
51	2042.82	.818	.25962	.5500	.593	.20232	.6276	.753	.24371	.5705
52	2123.72	.890	.27649	.5291	.657	.21919	.6037	.818	.25957	.5501
53	2206.18	.964	.29303	.5093	.721	.23574	.5811	.888	.27612	.5295
54	2290.22	2.038	.30927	.4906	.786	.25197	.5598	.960	.29235	.5101
55	2375.83	2.114	0.32521	0.4729	1.853	0.26791	0.5396	2.034	0.30829	0.4917

METRIC UNITS.

Cross sections and weights of wires.

Diam. in thousandths of a cm.	Area of cross section $(\frac{cm.}{1000})^2$	Copper — Density 8.90.			Iron — Density 7.80.			Brass — Density 8.56.		
		Grammes per Metre.	Log.	Metres per Gramme.	Grammes per Metre.	Log.	Metres per Gramme.	Grammes per Metre.	Log.	Metres per Gramme.
55	2375.83	2.114	0.32521	.4729	1.853	0.26791	.5396	2.034	0.30829	.4917
56	2463.01	.192	.34086	.4562	.921	.28356	.5205	.108	.32394	.4743
57	2551.76	.271	.35623	.4403	.990	.29893	.5024	.184	.33931	.4578
58	2642.08	.351	.37134	.4253	2.061	.31404	.4852	.262	.35442	.4422
59	2733.97	.433	.38618	.4112	.132	.32889	.4689	.340	.36927	.4273
60	2827.43	2.516	0.40078	.3974	2.205	0.34349	.4534	2.420	0.38387	.4132
61	2922.47	.601	.41514	.3845	.280	.35784	.4387	.502	.39823	.3997
62	3019.07	.687	.42926	.3722	.355	.37196	.4246	.584	.41235	.3869
63	3117.25	.774	.44316	.3604	.431	.38587	.4113	.668	.42625	.3748
64	3216.99	.863	.45684	.3493	.509	.39954	.3985	.760	.44092	.3623
65	3318.31	2.953	0.47031	.3386	2.588	0.41301	.3864	2.840	0.45339	.3521
66	3421.19	3.045	.48357	.3284	.669	.42627	.3747	.929	.46665	.3415
67	3525.65	.138	.49663	.3187	.750	.43933	.3636	3.018	.47971	.3313
68	3631.68	.232	.50950	.3094	.833	.45220	.3530	.109	.49258	.3217
69	3739.28	.328	.52218	.3005	.917	.46488	.3429	.201	.50526	.3124
70	3848.45	3.426	0.53479	.2919	3.003	0.47749	.3330	3.295	0.51787	.3035
71	3959.19	.524	.54700	.2838	.088	.48970	.3238	.389	.53008	.2951
72	4071.50	.624	.55915	.2759	.176	.50185	.3149	.485	.54223	.2869
73	4185.39	.725	.57113	.2685	.265	.51383	.3063	.583	.55421	.2791
74	4300.84	.828	.58294	.2612	.355	.52565	.2981	.682	.56603	.2716
75	4417.86	3.932	0.59460	.2543	3.446	0.53731	.2902	3.782	0.57769	.2644
76	4536.46	4.037	.60611	.2477	.538	.54881	.2826	.883	.58919	.2575
77	4656.63	.144	.61746	.2413	.632	.56017	.2753	.986	.60056	.2509
78	4778.36	.253	.62867	.2351	.727	.57137	.2683	4.090	.61175	.2445
79	4901.67	.362	.63974	.2292	.823	.58244	.2615	.177	.62283	.2394
80	5026.55	4.474	0.65066	.2235	3.921	0.59336	.2550	4.303	0.63375	.2324
81	5153.00	.586	.66145	.2180	4.019	.60415	.2488	.411	.64454	.2267
82	5281.02	.700	.67211	.2128	.119	.61481	.2428	.521	.65519	.2212
83	5410.61	.815	.68264	.2077	.220	.62534	.2369	.631	.66572	.2159
84	5541.77	.932	.69304	.2027	.323	.63574	.2313	.744	.67612	.2108
85	5674.50	5.050	0.70332	.1980	4.426	0.64602	.2259	4.857	0.68640	.2059
86	5808.80	.170	.71348	.1934	.531	.65618	.2207	.972	.69656	.2011
87	5944.68	.291	.72352	.1890	.637	.66622	.2157	5.089	.70660	.1965
88	6082.12	.413	.73345	.1847	.744	.67615	.2108	.206	.71653	.1921
89	6221.14	.537	.74326	.1806	.852	.68596	.2061	.325	.72634	.1878
90	6361.73	5.662	0.75297	.1766	4.962	0.69567	.2015	5.446	0.73605	.1836
91	6503.88	.788	.76256	.1728	5.073	.70527	.1971	.567	.74565	.1796
92	6647.61	.916	.77206	.1690	.185	.71476	.1929	.690	.75514	.1757
93	6792.91	6.046	.78144	.1654	.298	.72414	.1887	.815	.76452	.1720
94	6939.78	.176	.79074	.1619	.413	.73344	.1847	.940	.77382	.1683
95	7088.22	6.309	0.79993	.1585	5.529	0.74263	.1809	6.068	0.78301	.1648
96	7238.23	.442	.80902	.1552	.646	.75173	.1771	.196	.79211	.1614
97	7389.81	.577	.81802	.1520	.764	.76073	.1735	.326	.80111	.1581
98	7542.96	.713	.82693	.1490	.884	.76964	.1670	.457	.81002	.1549
99	7697.69	.851	.83575	.1460	6.004	.77846	.1665	.589	.81884	.1518
100	7853.98	6.990	0.84448	.1431	6.126	0.78718	.1632	6.723	0.82756	.1487

TABLE 31.

ZONAL HARMONICS.*

The values of the first seven zonal harmonics are here given for every degree between $\theta = 0°$ and $\theta = 90°$.

θ	z_1	z_2	z_3	z_4	z_5	z_6	z_7
0°	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1°	0.9998	0.9995	0.9991	0.9985	0.9977	0.9967	0.9955
2	.9994	.9982	.9963	.9939	.9909	.9872	.9829
3	.9986	.9959	.9918	.9863	.9795	.9713	.9617
4	.9976	.9927	.9854	.9758	.9638	.9495	.9329
5	.9962	.9886	.9773	.9623	.9437	.9216	.8961
6°	.9945	.9836	.9674	.9459	.9194	.8881	.8522
7	.9925	.9777	.9557	.9267	.8911	.8476	.7986
8	.9903	.9709	.9423	.9048	.8589	.8053	.7448
9	.9877	.9633	.9273	.8803	.8232	.7571	.6831
10	.9848	.9548	.9106	.8532	.7840	.7045	.6164
11°	.9816	.9454	.8923	.8238	.7417	.6483	.5461
12	.9781	.9352	.8724	.7920	.6966	.5892	.4732
13	.9744	.9241	.8511	.7582	.6489	.5273	.3940
14	.9703	.9122	.8283	.7224	.5990	.4635	.3219
15	.9659	.8995	.8042	.6847	.5471	.3982	.2454
16°	.9613	.8860	.7787	.6454	.4937	.3322	.1699
17	.9563	.8718	.7519	.6046	.4391	.2660	.0961
18	.9511	.8568	.7240	.5624	.3836	.2002	.0289
19	.9455	.8410	.6950	.5192	.3276	.1347	—.0443
20	.9397	.8245	.6649	.4750	.2715	.0719	—.1072
21°	.9336	.8074	.6338	.4300	.2156	.0107	—.1662
22	.9272	.7895	.6019	.3845	.1602	—.0481	—.2201
23	.9205	.7710	.5692	.3386	.1057	—.1038	—.2681
24	.9135	.7518	.5357	.2926	.0525	—.1559	—.3095
25	.9063	.7321	.5016	.2465	.0009	—.2053	—.3463
26°	.8988	.7117	.4670	.2007	—.0489	—.2478	—.3717
27	.8910	.6908	.4319	.1553	—.0964	—.2869	—.3921
28	.8829	.6694	.3964	.1105	—.1415	—.3211	—.4052
29	.8746	.6474	.3607	.0665	—.1839	—.3503	—.4114
30	.8660	.6250	.3248	.0234	—.2233	—.3740	—.4101
31°	.8572	.6021	.2887	—.0185	—.2595	—.3924	—.4022
32	.8480	.5788	.2527	—.0591	—.2923	—.4052	—.3876
33	.8387	.5551	.2167	—.0982	—.3216	—.4126	—.3670
34	.8290	.5310	.1809	—.1357	—.3473	—.4148	—.3409
35	.8192	.5065	.1454	—.1714	—.3691	—.4115	—.3096
36°	.8090	.4818	.1102	—.2052	—.3871	—.4031	—.2738
37	.7986	.4567	.0755	—.2370	—.4011	—.3898	—.2343
38	.7880	.4314	.0413	—.2666	—.4112	—.3719	—.1918
39	.7771	.4059	.0077	—.2940	—.4174	—.3497	—.1469
40	.7660	.3802	—.0252	—.3190	—.4197	—.3234	—.1003
41°	.7547	.3544	—.0574	—.3416	—.4181	—.2938	—.0534
42	.7431	.3284	—.0887	—.3616	—.4128	—.2611	—.0065
43	.7314	.3023	—.1191	—.3791	—.4038	—.2255	.0395
44	.7193	.2762	—.1485	—.3940	—.3914	—.1878	.0846
45	.7071	.2500	—.1768	—.4062	—.3757	—.1485	.1270

* Calculated by Prof. Perry (Phil. Mag. Dec. 1891). See also A. Gray, "Absolute Measurements in Electricity and Magnetism," vol. ii., part 2.

TABLE 39 (*continued*).

BRITISH AND METRIC UNITS.

Cross sections and weights of wires.

Diameter.*	Area of cross section.*	Aluminium — Density 2.67.								
		Pounds per Foot.	Log.	Feet per Pound.	Ounces per Foot.	Log.	Feet per Ounce.	Grammes per Metre.*	Log.	Metres per Gramme.
55	2375.83	.002750	$\bar{3}$.43934	363.6	.04400	$\bar{2}$.64346	22.73	0.6343	$\bar{1}$.80233	1.576
56	2463.01	2851	.45500	350.8	.04562	.65912	21.92	.6576	.81798	.521
57	2551.76	2954	.47037	338.6	.04726	.67449	21.16	.6813	.83335	.468
58	2642.08	3058	.48547	327.0	.04893	.68959	20.44	.7054	.84846	.418
59	2733.97	3165	.50032	316.0	.05063	.70444	19.75	.7300	.86331	.370
60	2827.43	.003273	$\bar{3}$.51492	305.5	.05236	$\bar{2}$.71904	19.10	0.7549	$\bar{1}$.87790	1.325
61	2922.47	3383	.52928	295.6	.05413	.73340	18.48	.7803	.89226	.282
62	3019.07	3495	.54340	286.2	.05591	.74752	17.88	.8061	.90638	.241
63	3117.25	3608	.55730	277.1	.05773	.76142	17.32	.8323	.92028	.201
64	3216.99	3724	.57098	268.5	.05958	.77510	16.78	8589	.93396	.164
65	3318.31	.003841	$\bar{3}$.58445	260.3	.06146	$\bar{2}$.78857	16.27	0.8860	$\bar{1}$.94743	1.129
66	3421.19	3960	.59771	252.5	.06336	.80183	15.78	.9135	.96069	.095
67	3525.65	4081	.61077	245.0	.06530	.81489	15.31	.9413	.97375	.062
68	3631.68	4204	.62364	237.9	.06726	.82777	14.87	.9697	.98662	.031
69	3739.28	4328	.63632	231.0	.06925	.84044	14.44	.9984	.99930	.002
70	3848.45	.004456	$\bar{3}$.64893	224.4	.07129	$\bar{2}$.85305	14.03	1.028	0.01191	0.9730
71	3959.19	4583	.66114	218.2	.07333	.86526	13.64	.057	.02412	.9460
72	4071.50	4713	.67328	212.2	.07541	.87740	13.26	.087	.03627	.9199
73	4185.39	4845	.68526	206.4	.07751	.88938	12.90	.117	.04825	.8949
74	4300.84	4978	.69708	200.9	.07965	.90120	12.55	.148	.06006	.8708
75	4417.86	.005114	$\bar{3}$.70874	195.5	.08182	$\bar{2}$.91286	12.22	1.180	0.07172	0.8477
76	4536.46	5251	.72025	190.4	.08402	.92437	11.90	.211	.08323	.8256
77	4656.63	5390	.73160	185.5	.08624	.93572	11.60	.243	.09458	.8043
78	4778.36	5531	.74281	180.8	.08850	.94693	11.30	.276	.10579	.7838
79	4901.67	5674	.75387	176.2	.09078	.95799	11.02	.309	.11686	.7641
80	5026.55	.005818	$\bar{3}$.76480	171.9	.09309	$\bar{2}$.96892	10.742	1.342	0.12778	0.7451
81	5153.00	5965	.77559	167.6	.09544	.97971	10.479	.376	.13857	.7268
82	5281.02	6113	.78625	163.6	.09781	.99037	10.224	.410	.14923	.7092
83	5410.61	6263	.79678	159.7	.10021	$\bar{1}$.00090	9.979	.445	.15976	.6922
84	5541.77	6415	.80718	155.9	.10264	.01130	9.743	.480	.17016	.6757
85	5674.50	.006568	$\bar{3}$.81746	152.2	.1051	$\bar{1}$.02158	9.515	1.515	0.18044	0.6600
86	5808.80	6724	.82762	148.7	.1076	.03174	9.295	.551	.19060	.6448
87	5944.68	6881	.83766	145.3	.1101	.04178	9.082	.587	.20064	.6300
88	6082.12	7040	.84758	142.0	.1126	.05170	8.878	.624	.21057	.6158
89	6221.14	7201	.85740	138.9	.1152	.06152	8.679	.661	.22038	.6020
90	6361.73	.007364	$\bar{3}$.86710	135.8	.1178	$\bar{1}$.07122	8.488	1.699	0.23009	0.5887
91	6503.88	7528	.87670	132.8	.1205	.08082	8.302	.737	.23968	.5759
92	6647.61	7695	.88619	130.0	.1231	.09031	8.122	.775	.24918	.5634
93	6792.91	7863	.89558	127.2	.1258	.09970	7.949	.814	.25856	.5514
94	6939.78	8033	.90487	124.5	.1285	.10899	7.780	.853	.26786	.5397
95	7088.22	.008205	$\bar{3}$.91407	121.9	.1313	$\bar{1}$.11819	7.617	1.893	0.27705	0.5284
96	7238.23	8378	.92316	119.4	.1341	.12728	7.459	.933	.28614	.5174
97	7389.81	8554	.93216	116.9	.1369	.13628	7.307	.973	.29514	.5068
98	7542.96	8731	.94107	114.5	.1397	.14519	7.158	2.014	.30405	.4965
99	7697.69	8910	.94989	112.2	.1426	.15401	7.015	.055	.31287	.4865
100	7853.98	.009091	$\bar{3}$.95862	110.0	.1455	$\bar{1}$.16274	6.875	2.097	0.32160	0.4769

* Columns 3–8, in thousandths of an inch; 9–12, thousandths of a centimetre.

TABLE 40.

SIZE, WEIGHT, AND ELECTRICAL

Size, Weight, and Electrical Constants of pure hard drawn Copper Wire of different numbers

Size and Weight.

Gauge Number.	Diameter in Inches.	Square of Diameter (Circular Inches).	Section in Sq. Inches.	Pounds per Foot.	Log.	Feet per Pound.
0000	0.4600	0.2116	0.1662	0.6412	$\bar{1}$.80701	1.560
000	.4096	.1678	.1318	.5085	.70631	1.967
00	.3648	.1331	.1045	.4033	.60560	2.480
0	.3249	.1055	.0829	.3198	.50489	3.127
1	0.2893	0.08369	0.06573	0.2536	$\bar{1}$.40419	3.943
2	.2576	.06637	.05213	.2011	.30348	4.972
3	.2294	.05263	.04134	.1595	.20277	6.270
4	.2043	.04174	.03278	.1265	.10206	7.905
5	.1819	.03310	.02600	.1003	.00136	9.969
6	0.1620	0.02625	0.02062	0.07955	$\bar{2}$.90065	12.57
7	.1443	.02082	.01635	.06309	.79994	15.85
8	.1285	.01651	.01297	.05003	.69924	19.99
9	.1144	.01309	.01028	.03968	.59853	25.20
10	.1019	.01038	.00815	.03146	.49782	31.78
11	0.09074	0.008234	0.006467	0.02495	$\bar{2}$.39711	40.08
12	.08081	.006530	.005129	.01979	.29641	50.54
13	.07196	.005178	.004067	.01569	.19570	63.72
14	.06408	.004107	.003225	.01244	.09499	80.35
15	.05707	.003257	.002558	.00987	$\bar{3}$.99429	101.32
16	0.05082	0.002583	0.002028	0.007827	$\bar{3}$.89358	127.8
17	.04526	.002048	.001609	.006207	.79287	161.1
18	.04030	.001624	.001276	.004922	.69217	203.2
19	.03589	.001288	.001012	.003904	.59146	256.2
20	.03196	.001021	.000802	.003096	.49075	323.1
21	0.02846	0.0008101	0.0006363	0.002455	$\bar{3}$.39004	408.2
22	.02535	.0006424	.0005046	.001947	.28934	513.6
23	.02257	.0005095	.0004001	.001544	.18863	647.7
24	.02010	.0004040	.0003173	.001224	.08792	816.7
25	.01790	.0003204	.0002517	.000971	$\bar{4}$.98722	1029.9
26	0.01594	0.0002541	0.0001996	0.0007700	$\bar{4}$.88651	1298.
27	.01419	.0002015	.0001583	.0006107	.78580	1638.
28	.01264	.0001598	.0001255	.0004843	.68510	2065.
29	.01126	.0001267	.0000995	.0003841	.58439	2604.
30	.01003	.0001005	.0000789	.0003046	.48368	3283.
31	0.008928	0.00007970	0.00006260	0.0002415	$\bar{4}$.38297	4140.
32	.007950	.00006321	.00004964	.0001915	.28227	5221.
33	.007080	.00005013	.00003937	.0001519	.18156	6583.
34	.006304	.00003975	.00003122	.0001205	.08085	8301.
35	.005614	.00003152	.00002476	.0000955	$\bar{5}$.98015	10468.
36	0.005000	0.00002500	0.00001963	0.00007576	$\bar{5}$.87944	13200.
37	.004453	.00001983	.00001557	.00006008	.77873	16644.
38	.003965	.00001372	.00001235	.00004765	.67802	20988.
39	.003531	.00001247	.00000979	.00003778	.57732	26465.
40	.003145	.00000989	.00000777	.00002996	.47661	33372.

CONSTANTS OF COPPER WIRE.

according to the American Brown and Sharp Gauge. Common Measure. Temperature 32° F. Density 8.90.

Electrical Constants.

Resistance and Conductivity.					Gauge Number.
Ohms per Foot.	Log.	Feet per Ohm.	Ohms per Pound.	Pounds per Ohm.	
0.00004629	$\bar{5}$.66551	21601.	0.00007219	13852.	0000
.00005837	.76622	17131.	.00011479	8712.	000
.00007361	.86693	13586.	.00018253	5479.	00
.00009282	.96764	10774.	.00029023	3445.	0
0.0001170	$\bar{4}$.06834	8544.	0.0004615	2166.8	1
.0001476	.16905	6775.	.0007338	1362.8	2
.0001861	.26976	5373.	.0011668	857.0	3
.0002347	.37046	4261.	.0018552	539.0	4
.0002959	.47117	3379.	.0029499	339.0	5
0.0003731	$\bar{4}$.57188	2680.	0.004690	213.22	6
.0004705	.67259	2125.	.007458	134.08	7
.0005933	.77329	1685.	.011859	84.32	8
.0007482	.87400	1337.	.018857	53.03	9
.0009434	.97471	1060.	.029984	33.35	10
0.001190	$\bar{3}$.07541	840.6	0.04768	20.973	11
.001500	.17612	666.6	.07581	13.191	12
.001892	.27683	528.7	.12054	8.296	13
.002385	.37753	419.2	.19166	5.218	14
.003008	.47824	332.5	.30476	3.281	15
0.003793	$\bar{3}$.57895	263.7	0.4846	2.0636	16
.004783	.67966	209.1	.7705	1.2979	17
.006031	.78036	165.8	1.2252	0.8162	18
.007604	.88107	131.5	1.9481	.5133	19
.009589	.98178	104.3	3.0976	.3228	20
0.01209	$\bar{2}$.08248	82.70	4.925	0.20305	21
.01525	.18319	65.59	7.832	.12768	22
.01923	.28390	52.01	12.453	.08030	23
.02424	.38461	41.25	19.801	.05051	24
.03057	.48531	32.71	31.484	.03176	25
0.03855	$\bar{2}$.58602	25.94	50.06	0.019976	26
.04861	.68673	20.57	79.60	.012563	27
.06130	.78743	16.31	126.57	.007901	28
.07729	.88814	12.94	201.26	.004969	29
.09746	.98885	10.26	320.01	.003125	30
0.1229	$\bar{1}$.08955	8.137	508.8	0.0019654	31
.1550	.19026	6.452	809.1	.0012359	32
.1954	.29097	5.117	1286.5	.0007773	33
.2464	.39168	4.058	2045.6	.0004889	34
.3107	.49238	3.218	3252.6	.0003074	35
0.3918	$\bar{1}$.59309	2.552	5172.	0.0001934	36
.4941	.69380	2.024	8224.	.0001216	37
.6230	.79450	1.605	13076.	.0000765	38
.7856	.89521	1.273	20792.	.0000481	39
.9906	.99592	1.009	33060.	.0000303	40

TABLE 41.

SIZE, WEIGHT, AND ELECTRICAL

Size, Weight, and Electrical Constants of pure hard drawn Copper Wire of different numbers

Size and Weight.

Gauge Number.	Diameter in Centimetres.	Square of Diameter (Circular Cms.).	Section in Sq. Cms.	Grammes per Metre.	Log.	Metres per Gramme.
0000	1.1684	1.3652	1.0722	954.3	2.97966	0.001048
000	.0405	.0826	0.8503	756.8	.87896	.001322
00	0.9266	0.8586	.6743	600.1	.77825	.001666
0	.8251	.6809	.5348	475.9	.67754	.002101
1	0.7348	0.5400	0.4241	377.4	2.57684	0.002649
2	.6544	.4282	.3363	299.3	.47613	.003341
3	.5827	.3396	.2667	237.4	.37542	.004213
4	.5189	.2693	.2115	188.2	.27472	.005312
5	.4621	.2136	.1677	149.3	.17401	.006699
6	0.4115	0.16936	0.13302	118.39	2.07330	0.00845
7	.3665	.13431	.10549	93.88	1.97259	.01065
8	.3264	.10651	.08366	74.45	.87189	.01343
9	.2906	.08447	.06634	59.04	.77118	.01694
10	.2588	.06699	.05261	46.82	.67047	.02136
11	0.2305	0.05312	0.04172	37.13	1.56977	0.02693
12	.2053	.04213	.03309	29.45	.46906	.03396
13	.1828	.03341	.02624	23.35	.36835	.04282
14	.1628	.02649	.02081	18.52	.26764	.05400
15	.1450	.02101	.01650	14.69	.16694	.06809
16	0.12908	0.016663	0.013087	11.648	1.06623	0.0859
17	.11495	.013214	.010378	9.237	0.96552	.1083
18	.10237	.010479	.008231	7.325	.86482	.1365
19	.09116	.008330	.006527	5.809	.76411	.1721
20	.08118	.006591	.005176	4.607	.66340	.2171
21	0.07229	0.005227	0.004105	3.653	0.56270	0.2737
22	.06438	.004145	.003255	2.898	.46199	.3450
23	.05733	.003287	.002582	2.298	.36128	.4352
24	.05106	.002607	.002047	1.822	.26057	.5488
25	.04545	.002067	.001624	1.445	.15987	.6920
26	0.04049	0.0016394	0.0012876	1.1459	0.05916	0.873
27	.03606	.0013001	.0010211	.9088	$\bar{1}$.95845	1.100
28	.03211	.0010310	.0008098	.7207	.85775	1.388
29	.02859	.0008176	.0006422	.5715	.75704	1.750
30	.02546	.0006484	.0005093	.4532	.65633	2.206
31	0.02268	0.0005142	0.0004039	0.3594	$\bar{1}$.55562	2.782
32	.02019	.0004078	.0003203	.2850	.45492	3.508
33	.01798	.0003234	.0002540	.2261	.35421	4.424
34	.01601	.0002565	.0002014	.1793	.25350	5.578
35	.01426	.0002034	.0001597	.1422	.15280	7.034
36	0.01270	0.0001613	0.0001267	0.1127	$\bar{1}$.05209	8.87
37	.01131	.0001279	.0001005	.0894	$\bar{2}$.95138	11.18
38	.01007	.0001014	.0000797	.0709	.85068	14.10
39	.00897	.0000804	.0000632	.0562	.74997	17.78
40	.00799	.0000638	.0000501	.0446	.64926	22.43

CONSTANTS OF COPPER WIRE.

according to the American Brown and Sharp Gauge. Metric Measure. Temperature 0° C. Density 8.90.

Electrical Constants.

Resistance and Conductivity.					Gauge Number.
Ohms per Metre.	Log.	Metres per Ohm.	Ohms per Gramme.	Grammes per Ohm.	
0.0001519	$\bar{4}$.18150	6584.	0.0000001592	6283000.	0000
.0001915	.28221	5221.	.0000002531	3951000.	000
.0002415	.38191	4141.	.0000004024	2485000.	00
.0003045	.48362	3284.	.0000006398	1563000.	0
0.0003840	$\bar{4}$.58433	2604.	0.0000001017	982900.	1
.0004842	.68503	2065.	.0000001618	618200.	2
.0006106	.78574	1638.	.0000002572	388800.	3
.0007699	.88645	1299.	.0000004090	244500.	4
.0009709	.98715	1030.	.0000006504	153800.	5
0.001224	$\bar{3}$.08786	816.9	0.00001034	96700.	6
.001544	.18857	647.8	.00001644	60820.	7
.001947	.28928	513.7	.00002615	38250.	8
.002455	.38998	407.4	.00004157	24050.	9
.003095	.49069	323.1	.00006610	15130.	10
0.003903	$\bar{3}$.59140	256.2	0.00010511	9514.	11
.004922	.69210	203.2	.00016712	5984.	12
.006206	.79281	161.1	.00026574	3763.	13
.007826	.89352	127.8	.00042254	2367.	14
.009868	.99423	101.3	.00067187	1488.	13
0.01244	$\bar{2}$.09493	80.37	0.0010683	936.1	16
.01569	.19564	63.73	.0016987	588.7	17
.01979	.29635	50.54	.0027010	370.2	18
.02495	.39705	40.08	.0042948	232.8	19
.03146	.49776	31.79	.0068290	146.4	20
0.03967	$\bar{2}$.59847	25.21	0.010859	92.09	21
.05002	.69917	19.99	.017266	57.92	22
.06308	.79988	15.85	.027454	36.42	23
.07954	.90059	12.57	.043653	22.91	24
.10030	$\bar{1}$.00130	9.97	.069411	11.88	25
0.12647	$\bar{1}$.10200	7.907	0.11037	9.060	26
.15948	.20271	6.270	.17549	5.698	27
.20110	.30342	4.973	.27904	3.584	28
.25358	.40412	3.943	.44369	2.254	29
.31976	.50483	3.127	.70550	1.417	30
0.4032	$\bar{1}$.60554	2.480	1.1218	0.8914	31
.5084	.70624	1.967	1.7837	.5606	32
.6411	.80695	1.560	2.8362	.3526	33
.8085	.90766	1.237	4.5097	.2217	34
1.0194	0.00837	0.981	7.1708	.1394	35
1.2855	0.10907	0.7779	11.376	0.08790	36
1.6210	.20978	.6169	18.130	.05516	37
2.0440	.31049	.4892	28.828	.03469	38
2.5775	.41119	.3880	45.838	.02182	39
3.2501	.51190	.3076	72.885	.01372	40

WEIGHT OF SHEET METAL.

TABLE 42. — Weight of Sheet Metal. (Metric Measure.)

This table gives the weight in grammes of a plate one metre square and of the thickness stated in the first column.

Thickness in thousandths of a cm.	Iron.	Copper.	Brass.	Aluminum.	Platinum.	Gold.	Silver.
1	78.0	89.0	85.6	26.7	215.0	193.0	105.0
2	156.0	178.0	171.2	53.4	430.0	386.0	210.0
3	234.0	267.0	256.8	80.1	645.0	579.0	315.0
4	312.0	356.0	342.4	106.8	860.0	772.0	420.0
5	390.0	445.0	428.0	133.5	1075.0	965.0	525.0
6	468.0	534.0	513.6	160.2	1290.0	1158.0	630.0
7	546.0	623.0	599.2	186.9	1505.0	1351.0	735.0
8	624.0	712.0	684.8	213.6	1720.0	1544.0	840.0
9	702.0	801.0	770.4	240.3	1935.0	1737.0	945.0
10	780.0	890.0	856.0	267.0	2150.0	1930.0	1050.0

TABLE 43. — Weight of Sheet Metal. (British Measure.)

Thickness in Mils.	Iron.	Copper.	Brass.	Aluminum.		Platinum.	
	Pounds per Sq. Foot.	Pounds per Sq. Foot.	Pounds per Sq. Foot.	Pounds per Sq. Foot.	Ounces per Sq. Foot.	Pounds per Sq. Foot.	Ounces per Sq. Foot.
1	.04058	.04630	.04454	.01389	.2222	.1119	1.790
2	.08116	.09260	.08908	.02778	.4445	.2237	3.579
3	.12173	.13890	.13363	.04167	.6667	.3356	5.369
4	.16231	.18520	.17817	.05556	.8890	.4474	7.158
5	.20289	.23150	.22271	.06945	1.1112	.5593	8.948
6	.24347	.27780	.26725	.08334	1.3335	.6711	10.738
7	.28405	.32411	.31179	.09723	1.5557	.7830	12.527
8	.32463	.37041	.35634	.11112	1.7780	.8948	14.317
9	.36520	.41671	.40088	.12501	2.0002	1.0067	16.106
10	.40578	.46301	.44542	.13890	2.2224	1.1185	17.896

Thickness in Mils.	Gold.		Silver.	
	Troy Ounces per Sq. Foot.	Grains per Sq. Foot.	Troy Ounces per Sq. Foot.	Grains per Sq. Foot.
1	1.4642	702.8	0.7967	382.4
2	2.9285	1405.7	1.5933	764.8
3	4.3927	2108.5	2.3900	1147.2
4	5.8570	2811.3	3.1867	1529.6
5	7.3212	3514.2	3.9833	1912.0
6	8.7854	4217.0	4.7800	2294.4
7	10.2497	4919.8	5.5767	2676.8
8	11.7139	5622.7	6.3734	3059.2
9	13.1782	6325.5	7.1700	3441.6
10	14.6424	7028.3	7.9667	3824.0

STRENGTH OF MATERIALS.

The strength of most materials varies so that the following figures serve only as a rough indication of the strength of a particular sample.

TABLE 44 (a). — Metals.

Name of Metal.	Tensile strength in pounds per sq. in.
Aluminum wire	30000–40000
Brass wire	50000–150000
Bronze wire, phosphor, hard-drawn	110000–140000
Bronze wire, silicon, hard-drawn	95000–115000
Bronze: Cu, 58.54 parts; Zn, 38.70; Al, 0.21; with 2.55 parts of the alloy, Sn, 29.03, wrought iron, 58.06, ferro-manganese, 12.91	60000–75000
Copper wire, hard-drawn	60000–70000
Gold wire	20000
Iron, cast	13000–33000
" wire, hard-drawn	80000–120000
" " annealed	50000–60000
Lead, cast or drawn	2600–3300
Palladium *	39000
Platinum * wire	50000
Silver * wire	42000
Steel	80000–330000
" wire, maximum	460000
" Specially treated nickel-steel, approx. comp. 0.40 C; 3.25 Ni; treatment secret	250000
" piano wire, 0.033 in. diam.	357000–390000
" piano wire, 0.051 in. diam.	325000–337000
Tin, cast or drawn	4000–5000
Zinc, cast	7000–13000
" drawn	22000–30000

According to Boys, quartz fibres have a tensile strength of between 116000 and 167000 pounds per square inch.

* Authority of Wertheim.

TABLE 44 (b). — Stones.*

Material.	Size of test piece.	Resistance to crushing in pds. per sq. in.
Marble	4 in. cubes	7600–20700
Tufa	2 " "	7700–11600
Brownstone	– – –	7300–23600
Sandstone	4 in. cubes	2400–29300
Granite	4 " "	9700–34000
Limestone	4 " "	6000–25000

* Data furnished by the U. S. Geological Survey.

TABLE 44 (c). — Brick.*

Kind of Brick.	Resistance to crushing in pds. per sq. in.	
	Tested flatwise.	Tested on edge.
Soft burned	1800–4000	1600–3000
Medium burned	4000–6000	3000–4500
Hard burned	6000–8500	4500–6500
Vitrified	8500–25000	6500–20000
Sand-lime	1800–4000	

Brick piers laid up in 1 part Portland cement, 3 of sand, have from 20 to 40 per cent the crushing strength of the brick.

* Data furnished by the U. S. Geological Survey.

TABLE 44 (d). — Concretes.*

Coarse material. "Aggregate."	Proportions by volume. Cement : sand : aggregate.	Size of test piece.	Resistance to crushing in pds. per sq. in.
Sandstone	1 : 5 : 14 to 1 : 1 : 5	12 in. cube	1550–3860
Cinders	1 : 3 : 6 " 1 : 1 : 3	12 " "	790–2050
Limestone	1 : 4 : 8 " 1 : 2 : 4	12 " "	1200–2840
Conglomerate	1 : 6 : 12 " 1 : 2 : 4	12 " "	1080–3830
Trap	1 : 2 : 9 " 1 : 2 : 4	12 " "	820–2960

* Data furnished by the U. S. Geological Survey.

STRENGTH OF MATERIALS.

Average Results of Timber Tests.

The test pieces were SMALL and SELECTED. Endwise compression tests of some of the first lot, made when green and containing over 40 per cent moisture, showed a diminishing in strength of 50 to 75 per cent.

See also Table 46. A particular sample may vary greatly from these data, which can indicate only in a general way the relative values of a kind of timber. Note that the data below are from selected samples and therefore probably high.

The upper lot are from the U. S. Forestry circular No. 15; the lower from the tests made for the 10th U. S. Census.

NAME OF SPECIES.	TRANSVERSE TESTS.		COMPRESSION.		SHEARING.
	Modulus of rupture. lb./sq. in.	Modulus of elasticity. lbs./sq. in.	∥ to grain. lbs./sq. in.	⊥ to grain. lbs./sq. in.	Along the grain. lbs./sq. in.
Long-leaf pine	12,600	2,070,000	8,000	1260	835
Cuban pine	13,600	2,370,000	8,700	1200	770
Short-leaf pine	10,100	1,680,000	6,500	1050	770
Loblolly pine	11,300	2,050,000	7,400	1150	800
White pine	7,900	1,390,000	5,400	700	400
Red pine	9,100	1,620,000	6,700	1000	500
Spruce pine	10,000	1,640,000	7,300	1200	800
Bald cypress	7,900	1,290,000	6,000	800	500
White cedar	6,300	910,000	5,200	700	400
Douglass spruce	7,900	1,680,000	5,700	800	500
White oak	13,100	2,090,000	8,500	2200	1000
Overcup oak	11,300	1,620,000	7,300	1900	1000
Post oak	12,300	2,030,000	7,100	3000	1100
Cow oak	11,500	1,610,000	7,400	1900	900
Red oak	11,400	1,970,000	7,200	2300	1100
Texan oak	13,100	1,860,000	8,100	2000	900
Yellow oak	10,800	1,740,000	7,300	1800	1100
Water oak	12,400	2,000,000	7,800	2000	1100
Willow oak	10,400	1,750,000	7,200	1600	900
Spanish oak	12,000	1,930,000	7,700	1800	900
Shagbark hickory	16,000	2,390,000	9,500	2700	1100
Mockernut hickory	15,200	2,320,000	10,100	3100	1100
Water hickory	12,500	2,080,000	8,400	2400	1000
Bitternut hickory	15,000	2,280,000	9,600	2200	1000
Nutmeg hickory	12,500	1,940,000	8,800	2700	1100
Pecan hickory	15,300	2,530,000	9,100	2800	1200
Pignut hickory	18,700	2,730,000	10,900	3200	1200
White elm	10,300	1,540,000	6,500	1200	800
Cedar elm	13,500	1,700,000	8,000	2100	1300
White ash	10,800	1,640,000	7,200	1900	1100
Green ash	11,600	2,050,000	8,000	1700	1000
Sweet gum	9,500	1,700,000	7,100	1400	800
Poplar	9,400	1,330,000	5,000	1120	
Basswood	8,340	1,172,000	5,190	880	
Ironwood	7,540	1,158,000	5,275	2000	
Sugar maple	16,500	2,250,000	8,800	3600	
White maple	14,640	1,800,000	6,850	2580	
Box elder	7,580	873,000	4,580	1580	
Black walnut	11,900	1,560,000	8,000	2680	
Sycamore	7,000	790,000	6,400	2700	
Hemlock	9,480	1,138,000	5,400	1100	
Red fir	13,270	1,870,000	7,780	1750	
Tamarack	13,150	1,917,000	7,400	1480	
Red cedar	11,800	938,000	6,300	2000	
Cottonwood	10,440	1,450,000	5,000	1100	
Beech	16,200	1,730,000	6,770	2840	

TABLE 46.

UNIT STRESSES FOR STRUCTURAL TIMBER EXPRESSED IN POUNDS PER SQUARE INCH.

Recommended by the Committee on Wooden Bridges and Trestles, American Railway Engineering Association, 1909.

KIND OF TIMBER.	BENDING.			SHEARING.			
	Extreme fibre stress.		Modulus of elasticity.	Parallel to grain.		Longitudinal shear in beams.	
	Average ultimate.	Safe stress.	Average.	Average ultimate.	Safe stress.	Average ultimate.	Safe stress.
Douglass fir	6100	1200	1,510,000	690	170	270	110
Long-leaf pine	6500	1300	1,610,000	720	180	300	120
Short-leaf pine	5600	1100	1,480,000	710	170	330	130
White pine	4400	900	1,130,000	400	100	180	70
Spruce	4800	1000	1,310,000	600	150	170	70
Norway pine	4200	800	1,190,000	590	130	250	100
Tamarack	4600	900	1,220,000	670	170	260	100
Western hemlock	5800	1100	1,480,000	630	160	270*	100
Redwood	5000	900	800,000	300	80	–	–
Bald cypress	4800	900	1,150,000	500	120	–	–
Red cedar	4200	800	860,000	–	–	–	–
White oak	5700	1100	1,150,000	840	210	270	110

KIND OF TIMBER.	COMPRESSION.						Ratio of length of stringer to depth.
	Perpendicular to grain.		Parallel to grain.		For columns under 15 diams. Safe stress.	Formulas for safe stress in long columns over 15 diameters.†	
	Elastic limit.	Safe stress.	Average ultimate.	Safe stress.			
Douglas fir	630	310	3600	1200	900	1200(1–L/60.D)	10
Long-leaf pine	520	260	3800	1300	980	1300(1–L/60.D)	10
Short-leaf pine	340	170	3400	1100	830	1100(1–L/60.D)	10
White pine	290	150	3000	1000	750	1000(1–L/60.D)	10
Spruce	370	180	3200	1100	830	1100(1–L/60.D)	–
Norway pine	–	150	2600*	800	600	800(1–L/60.D)	–
Tamarack	–	220	3200*	1000	750	1000(1–L/60.D)	–
Western hemlock	440	220	3500	1200	900	1200(1–L/60.D)	–
Redwood	400	150	3300	900	680	900(1–L/60.D)	–
Bald cypress	340	170	3900	1100	830	1100(1–L/60.D)	–
Red cedar	470	230	2800	900	680	900(1–L/60.D)	–
White oak	920	450	3500	1300	980	1300(1–L/60.D)	12

These unit stresses are for a green condition of the timber and are to be used without increasing the live-load stresses for impact.

* Partially air-dry.

† L = length in inches. D = least side in inches.

ELASTIC MODULI.

TABLE 47. — Rigidity Modulus.

If to the four consecutive faces of a cube a tangential stress is applied, opposite in direction on adjacent sides, the modulus of rigidity is obtained by dividing the numerical value of the tangential stress per unit area (kg. per sq. mm.) by the number representing the change of angles on the non-stressed faces, measured in radians.

Substance.	Rigidity Modulus.	Reference.	Substance.	Rigidity Modulus.	Reference.
Aluminum	3350	14	Quartz fibre	2888	20
" cast	2580	5	" "	2380	21
Brass	3550	10	Silver	2960	5
"	3715	11	"	2650	10
" cast, 60 Cu + 12 Sn	3700	5	"	2566	16
Bismuth, slowly cooled	1240	5	" hard-drawn	2816	11
Bronze, cast, 88 Cu + 12 Sn	4060	5	Steel	8290	16
Cadmium, cast	2450	5	" cast	7458	15
Copper, cast	4780	5	" cast, coarse gr.	8070	5
"	4213	18	" silver-	7872	11
"	4450	10	Tin, cast	1730	5
"	4664	19	"	1543	19
Gold	2850	5	Zinc	3880	5
"	3950	14	"	3820	19
Iron, cast	5210	5	Platinum	6630	16
"	6706	15	"	6220	22
"	7975	10	Glass	2350	–
"	6940	7	"	2730	–
"	8108	16	Clay rock	1770	23
"	7505	14	Granite	1280	23
Magnesium, cast	1710	5	Marble	1190	23
Nickel	7820	5	Slate	2290	23
Phosphor bronze	4359	11			

References 1–16, see Table 48.
17 Grätz, Wied. Ann. 28, 1886.
18 Savart, Pogg. Ann. 16, 1829.
19 Kiewiet, Diss. Göttingen, 1886.
20 Threlfall, Philos. Mag. (5) 30, 1890.
21 Boys, Philos. Mag. (5) 30, 1890.
22 Thomson, Lord Kelvin.
23 Gray and Milne.
24 Adams-Coker, Carnegie Publ. No. 46, 1906.

TABLE 47a. — Variation of the Rigidity Modulus with the Temperature.

$n_t = n_o (1 - \alpha t - \beta t^2 - \gamma t^3)$, where t = temperature Centigrade.

Substance.	n_o	$\alpha 10^5$	$\beta 10^8$	$\gamma 10^{10}$	Authority.
Brass	2652	2158	48	32	Pisati, Nuovo Cimento, 5, 34, 1879.
"	3200	455	36	–	Kohlrausch-Loomis, Pogg. Ann. 141.
Copper	3972	2716	—23	47	Pisati, loc. cit.
"	3900	572	28	–	K and L, loc. cit.
Iron	8108	206	19	—11	Pisati, loc. cit.
"	6940	483	12	–	K and L, loc. cit.
Platinum	6632	111	50	—8	Pisati, loc. cit.
Silver	2566	387	38	11	" " "
Steel	8290	187	59	—9	" " "

$n_t^* = n_{15} [1 - \alpha (t - 15)]$; Horton, Philos. Trans. 204 A, 1905.

Copper	4.37*	α = .00039	Platinum	6.46*	α = .00012	Tin	1.50*	α = .00416
Copper (commercial)	3.80	.00038	Gold	2.45	.00031	Lead	0.80	.00164
Iron	8.26	.00029	Silver	2.67	.00048	Cadmium	2.31	.0058
Steel	8.45	.00026	Aluminum	2.55	.00148	Quartz	3.00	.00012

* Modulus of rigidity in 10^{11} dynes per sq. cm.

ELASTIC MODULI.

Young's Modulus.

$$\text{Young's Modulus} = \frac{\text{Intensity of longitudinal stress (kg. per sq. mm.)}}{\text{Elongation per unit length}}$$

Substance.	Temp. °C.	Young's Modulus.	Reference.
Aluminum	20	7200	1
"	12.3	7462	2
Lead, drawn	15	1803	3
" annealed	15	1727	3
Bronze	–	9194	4
Cadmium	–	7070	5
Delta metal	–	11697	6
Iron, drawn	15	20869	3
" annealed	15	20794	3
"	0	20310	7
"	–	21740	8
" cast	–	11713	4
" soft	15.6	15750	9
" drawn	20	19385	1
" drawn	–	20500	10
Gold, drawn	15	8131	3
" annealed	15	5585	3
" drawn	12.9	8630	2
Copper, drawn	15	12450	3
" annealed	15	10520	3
" drawn	0	12140	7
" drawn	20	12550	1
" electr. h'd d'n	19.5	13220	9
Brass, drawn	15	8543	3
"	0	9810	7
" drawn	–	10220	11
"	–	9930	10
"	–	10450	9
German silver	–	12094	4
" " h'd d'n	–	11550	11
" "	20	13300	9
Nickel	–	20300	5
"	–	22790	12
" hard drawn	–	23950	11
"	11.5	21680	2
Nickel-steel, 5½% ni.	–	19900	13
" " 25% "	–	18600	13
Palladium, annealed	15	9709	3
Phosphor-bronze	–	12010	11
Platinum, drawn	15	17044	3
" annealed	15	15518	3
"	13.2	16020	2
" drawn	10	15989	1
Silver, drawn	15	7357	3
" annealed	15	7140	3
Steel wire, drawn	15	18810	3
" " annealed	15	17280	3
Steel, cast, drawn	15	19550	3
" " annealed	15	19560	3
" Bessemer	–	21136	4
" puddle	–	21112	4
" mild	15.5	21700	9
" very soft	–	20705	13
" half soft	–	20910	13
" hard	–	20600	13
Bismuth	–	3190	5
Zinc, drawn	15	8734	3
Tin, drawn	15	4148	3
" cast	–	1700	13
Glass	–	6000 to 8000	–
Carbon	–	1500 to 2500	–
Marbles	–	6316	24
Granites	–	5159	24
Basic intrusives	–	8985	24
Rocks: See Nagaoka, Philos. Mag. 1900.			

1 Slotte, Acta Soc. Fenn. 26, 1899; 29, 1900.
2 Meyer, Wied. Ann. 59, 1896.
3 Wertheim, Ann. chim. phys. (3) 12, 1844.
4 Pscheidl, Wien. Ber. II, 79, 1879.
5 Voigt, Wied. Ann. 48, 1893.
6 Amagat, C. R. 108, 1889.
7 Kohlrausch, Loomis, Pogg. Ann. 141, 1871.
8 Thomas, Drude Ann. 1, 1900.
9 Gray, etc., Proc. Roy. Soc. 67, 1900.
10 Baumeister, Wied. Ann. 18, 1883.
11 Searle, Philos. Mag. (5) 49, 1900.
12 Cantone, Wied. Beibl. 14, 1890.
13 Mercadier, C. R. 113, 1891.
14 Katzenelsohn, Diss. Berlin, 1887.
15 Wertheim, Pogg. Ann. 78, 1849.
16 Pisati, Nuovo Cimento, 5, 34, 1879.
References 17–19, see Table 47.

Compiled partly from Landolt-Börnstein's Physikalisch-Chemische Tabellen.

COMPRESSIBILITY, HARDNESS, CONTRACTION OF ELEMENTS.

TABLE 49. — Compressibility of the More Important Solid Elements.

Arranged in order of the increasing atomic weights. The numbers give the mean elastic change of volume for one megabar (0.987 atm.) between 100 and 500 megabars, multiplied by 10^6.

Lithium	8.8	Potassium	31.5	Selenium	11.8	Iodine	13.
Carbon	0.5	Calcium	5.5	Bromine	51.8	Cæsium	61.
Sodium	15.4	Chromium	0.7	Rubidium	40.	Platinum	0.21
Magnesium	2.7	Manganese	0.7	Molybdium	0.26	Gold	0.47
Aluminum	1.3	Iron	0.40	Palladium	0.38	Mercury	3.71
Silicon	0.16	Nickel	0.27	Silver	0.84	Thallium	2.6
Red phosphorus	9.0	Copper	0.54	Cadmium	1 9	Lead	2.2
Sulphur	12.5	Zinc	1.5	Tin	1.6	Bismuth	2.8
Chlorine	95.	Arsenic	4.3	Antimony	2.2		

Stull, Zeitschr. Phys. Chem 61, 1907.

TABLE 50.— Hardness.

Agate	7.	Brass	3-4.	Iridosmium	7.	Sulphur	1.5-2.5
Alabaster	1.7	Calimine	5.	Iron	4-5.	Stibnite	2.
Alum	2-2.5	Calcite	3.	Kaolin	1.	Serpentine	3-4.
Aluminum	2.	Copper	2.5-3.	Loess (0°)	0.3	Silver	2.5-3.
Amber	2-2.5	Corundum	9.	Magnetite	6.	Steel	5-8.5
Andalusite	7.5	Diamond	10.	Marble	3-4.	Talc	1.
Anthracite	2.2	Dolomite	3.5-4.	Meerschaum	2-3.	Tin	1.5
Antimony	3.3	Feldspar	6.	Mica	2.8	Topaz	8.
Apatite	5.	Flint	7.	Opal	4-6.	Tourmaline	7.3
Aragonite	3.5	Fluorite	4.	Orthoclase	6.	Wax (0°)	0.2
Arsenic	3.5	Galena	2.5	Palladium	4.8	Wood's metal	3.
Asbestos	5.	Garnet	7.	Phosphorbronze	4.		
Asphalt	1-2.	Glass	4.5-6.5	Platinum	4.3		
Augite	6.	Gold	2.5-3.	Plat-iridium	6.5		
Barite	3.3	Graphite	0.5-1.	Pyrite	6.3		
Beryl	7.8	Gypsum	1.6-2.	Quartz	7.		
Bell-metal	4.	Hematite	6.	Rock-salt	2.		
Bismuth	2.5	Hornblende	5.5	Ross' metal	2.5-3.0		
Boric acid	3.	Iridium	6.	Silver chloride	1.3		

From Landolt-Börnstein-Meyerhoffer Tables: Auerbachs, Winklemann, Handb. der Phys. 1891.

TABLE 51.— Relative Hardness of the Elements.

C	10.0	Ru	6.5	Cu	3.0	Au	2.5	Sn	1.8	Li	0.6
B	9.5	Mn	5.0	Sb	3.0	Te	2.3	Sr	1.8	P	0.5
Cr	9.0	Pd	4.8	Al	2.9	Cd	2.0	Ca	1.5	K	0.5
Os	7.0	Fe	4.5	Ag	2.7	S	2.0	Ga	1.5	Na	0.4
Si	7.0	Pt	4.3	Bi	2.5	Se	2.0	Pb	1.5	Rb	0.3
Ir	6.5	As	3.5	Zn	2.5	Mg	2.0	In	1.2	Cs	0.2

Rydberg, Zeitschr. Phys. Chem. 33, 1900.

TABLE 52.— Ratio, ρ, of Transverse Contraction to Longitudinal Extension under Tensile Stress.
(Poisson's Ratio.)

Metal	Pb	Au	Pd	Pt	Ag	Cu	Al	Bi	Sn	Ni	Cd	Fe
ρ	0.45	0.42	0.39	0.39	0.38	0.35	0.34	0.33	0.33	0.31	0.30	0.28

From data from Physikalisch-Technischen Reichsanstalt, 1907.
ρ for: marbles, 0.27; granites, 0.24; basic-intrusives, 0.26; glass, 0.23. Adams-Coker, 1906.

ELASTICITY OF CRYSTALS.*

The formulæ were deduced from experiments made on rectangular prismatic bars cut from the crystal. These bars were subjected to cross bending and twisting and the corresponding Elastic Moduli deduced. The symbols $\alpha\ \beta\ \gamma$, $\alpha_1\ \beta_1\ \gamma_1$ and $\alpha_2\ \beta_2\ \gamma_2$ represent the direction cosines of the length, the greater and the less transverse dimensions of the prism with reference to the principal axis of the crystal. E is the modulus for extension or compression, and T is the modulus for torsional rigidity. The moduli are in grammes per square centimetre.

Barite.

$$\frac{10^{10}}{E} = 16.13\alpha^4 + 18.51\beta^4 + 10.42\gamma^4 + 2(38.79\beta^2\gamma^2 + 15.21\gamma^2\alpha^2 + 8.88\alpha^2\beta^2)$$

$$\frac{10^{10}}{T} = 69.52\alpha^4 + 117.66\beta^4 + 116.46\gamma^4 + 2(20.16\beta^2\gamma^2 + 85.29\gamma^2\alpha^2 + 127.35\alpha^2\beta^2)$$

Beryl (Emerald).

$$\frac{10^{10}}{E} = 4.325\sin^4\phi + 4.619\cos^4\phi + 13.328\sin^2\phi\cos^2\phi$$

$$\frac{10^{10}}{T} = 15.00 - 3.675\cos^4\phi_2 - 17.536\cos^2\phi\cos^2\phi_1$$

where $\phi\ \phi_1\ \phi_2$ are the angles which the length, breadth, and thickness of the specimen make with the principal axis of the crystal.

Fluor spar.

$$\frac{10^{10}}{E} = 13.05 - 6.26(\alpha^4 + \beta^4 + \gamma^4)$$

$$\frac{10^{10}}{T} = 58.04 - 50.08(\beta^2\gamma^2 + \gamma^2\alpha^2 + \alpha^2\beta^2)$$

Pyrites.

$$\frac{10^{10}}{E} = 5.08 - 2.24(\alpha^4 + \beta^4 + \gamma^4)$$

$$\frac{10^{10}}{T} = 18.60 - 17.95(\beta^2\gamma^2 + \gamma^2\alpha^2 + \alpha^2\beta^2)$$

Rock salt.

$$\frac{10^{10}}{E} = 33.48 - 9.66(\alpha^4 + \beta^4 + \gamma^4)$$

$$\frac{10^{10}}{T} = 154.58 - 77.28(\beta^2\gamma^2 + \gamma^2\alpha^2 + \alpha^2\beta^2)$$

Sylvine.

$$\frac{10^{10}}{E} = 75.1 - 48.2(\alpha^4 + \beta^4 + \gamma^4)$$

$$\frac{10^{10}}{T} = 306.0 - 192.8(\beta^2\gamma^2 + \gamma^2\alpha^2 + \alpha^2\beta^2)$$

Topaz.

$$\frac{10^{10}}{E} = 4.341\alpha^4 + 3.460\beta^4 + 3.771\gamma^4 + 2(3.879\beta^2\gamma^2 + 2.856\gamma^2\alpha^2 + 2.39\alpha^2\beta^2)$$

$$\frac{10^{10}}{T} = 14.88\alpha^4 + 16.54\beta^4 + 16.45\gamma^4 + 30.89\beta^2\gamma^2 + 40.89\gamma^2\alpha^2 + 43.51\alpha^2\beta^2$$

Quartz.

$$\frac{10^{10}}{E} = 12.734(1-\gamma^2)^2 + 16.693(1-\gamma^2)\gamma^2 + 9.705\gamma^4 - 8.460\beta\gamma(3\alpha^2 - \beta^2)$$

$$\frac{10^{10}}{T} = 19.665 + 9.060\gamma_2^2 + 22.984\gamma^2\gamma_1^2 - 16.920[(\gamma\beta_1 + \beta\gamma_1)(3\alpha\alpha_1 - \beta\beta_1) - \beta_2\gamma_2)]$$

* These formulæ are taken from Voigt's papers (Wied. Ann. vols. 31, 34, and 35).

TABLE 54.

ELASTICITY OF CRYSTALS.

Some particular values of the Elastic Moduli are here given. Under E are given moduli for extension or compression in the directions indicated by the subscripts and explained in the notes, and under T the moduli for torsional rigidities round the axes similarly indicated.

(*a*) REGULAR SYSTEM.*

Substance.	E_a	E_b	E_c	T_a	Authority.
Fluor spar	1473×10^6	1008×10^6	910×10^6	345×10^6	Voigt.†
Pyrites	3530×10^6	2530×10^6	2310×10^6	1075×10^6	"
Rock salt	419×10^6	349×10^6	303×10^6	129×10^6	"
"	403×10^6	339×10^6	—	—	Koch.‡
Sylvine	401×10^6	209×10^6	—	—	"
"	372×10^6	196×10^6	—	655×10^6	Voigt.
Sodium chloride	405×10^6	319×10^6	—	—	Koch.
Potash alum	181×10^6	199×10^6	—	—	Beckenkamp.§
Chrome alum	161×10^6	177×10^6	—	—	"
Iron alum	186×10^6	—	—	—	"

(*b*) RHOMBIC SYSTEM.‖

Substance.	E_1	E_2	E_3	E_4	E_5	E_6	Authority.
Barite	620×10^6	540×10^6	959×10^6	376×10^6	702×10^6	740×10^6	Voigt.
Topaz	2304×10^6	2890×10^6	2652×10^6	2670×10^6	2893×10^6	3180×10^6	"

Substance.	$T_{12} = T_{21}$	$T_{13} = T_{31}$	$T_{23} = T_{32}$	Authority.
Barite	283×10^6	293×10^6	121×10^6	Voigt.
Topaz	1336×10^6	1353×10^6	1104×10^6	"

In the MONOCLINIC SYSTEM, Coromilas (Zeit. für Kryst. vol. 1) gives

Gypsum $\begin{cases} E_{max} = 887 \times 10^6 \text{ at } 21.9^\circ \text{ to the principal axis.} \\ E_{min} = 313 \times 10^6 \text{ at } 75.4^\circ \quad " \quad " \quad " \end{cases}$

Mica $\begin{cases} E_{max} = 2213 \times 10^6 \text{ in the principal axis.} \\ E_{min} = 1554 \times 10^6 \text{ at } 45^\circ \text{ to the principal axis.} \end{cases}$

In the HEXAGONAL SYSTEM, Voigt gives measurements on a beryl crystal (emerald). The subscripts indicate inclination in degrees of the axis of stress to the principal axis of the crystal.

$E_0 = 2165 \times 10^6$, $E_{45} = 1796 \times 10^6$, $E_{90} = 2312 \times 10^6$,

$T_0 = 667 \times 10^6$, $T_{90} = 883 \times 10^6$. The smallest cross dimension of the prism experimented on (see Table 82), was in the principal axis for this last case.

In the RHOMBOHEDRIC SYSTEM, Voigt has measured quartz. The subscripts have the same meaning as in the hexagonal system.

$E_0 = 1030 \times 10^6$, $E_{-45} = 1305 \times 10^6$, $E_{+45} = 850 \times 10^6$, $E_{90} = 785 \times 10^6$,

$T_0 = 508 \times 10^6$, $T_{90} = 348 \times 10^6$.

Baumgarten ¶ gives for calcspar

$E_0 = 501 \times 10^6$, $E_{-45} = 441 \times 10^6$, $E_{+45} = 772 \times 10^6$, $E_{90} = 790 \times 10^6$.

* In this system the subscript *a* indicates that compression or extension takes place along the crystalline axis, and distortion round the axis. The subscripts *b* and *c* correspond to directions equally inclined to two and normal to the third and equally inclined to all three axes respectively.

† Voigt, "Wied. Ann." vol. 31, 34-35; 36, 642.

‡ Koch, "Wied. Ann." vol. 18.

§ Beckenkamp, "Zeit. für Kryst." vol. 10.

‖ The subscripts 1, 2, 3 indicate that the three principal axes are the axes of stress; 4, 5, 6 that the axes of stress are in the three principal planes at angles of 45° to the corresponding axes.

¶ Baumgarten, "Pogg. Ann." vol. 152.

COMPRESSIBILITY OF GASES.

TABLE 55.—Relative Volumes at Various Pressures and Temperatures, the volume at 0° C and at 1 atmosphere being taken as 1 000 000.

Atm.	Oxygen.			Air.			Nitrogen.			Hydrogen.		
	0°	99°.5	199°.5	0°	99°.4	200°.4	0°	99°.5	199°.6	0°	99°.3	200°.5
100	9265	–	–	9730	–	–	9910	–	–	–	–	–
200	4570	7000	9095	5050	7360	9430	5195	7445	9532	5690	7567	9420
300	3208	4843	6283	3658	5170	6622	3786	5301	6715	4030	5286	6520
400	2629	3830	4900	3036	4170	5240	3142	4265	5331	3207	4147	5075
500	2312	3244	4100	2680	3565	4422	2780	3655	4515	2713	3462	4210
600	2115	2867	3570	2450	3180	3883	2543	3258	3973	2387	3006	3627
700	1979	2610	3202	2288	2904	3502	2374	2980	3589	2149	2680	3212
800	1879	2417	2929	2168	2699	3219	2240	2775	3300	1972	2444	2900
900	1800	2268	2718	2070	2544	3000	2149	2616	3085	1832	2244	2657
1000	1735	2151	–	1992	2415	2828	2068	–	–	1720	2093	–

Amagat: C. R. 111, 1890; Ann. chim. phys. (6) 29, 1893.

TABLE 56.—Ethylene.

pv at 0° C and 1 atm. = 1.

Atm.	0°	10°	20°	30°	40°	60°	80°	100°	137°.5	198°.5
46	–	0.562	0.684	–	–	–	–	–	–	–
48	–	0.508	–	–	–	–	–	–	–	–
50	0.176	0.420	0.629	0.731	0.814	0.954	1.077	1.192	1.374	1.652
52	–	0.240	0.598	–	–	–	–	–	–	–
54	–	0.229	0.561	–	–	–	–	–	–	–
56	–	0.227	0.524	–	–	–	–	–	–	–
100	0.310	0.331	0.360	0.403	0.471	0.668	0.847	1.005	1.247	1.580
150	0.441	0.459	0.485	0.515	0.551	0.649	0.776	0.924	1.178	1.540
200	0.565	0.585	0.610	0.638	0.669	0.744	0.838	0.946	1.174	1.537
300	0.806	0.827	0.852	0.878	0.908	0.972	1.048	1.133	1.310	1.628
500	1.256	1.280	1.308	1.337	1.367	1.431	1.500	1.578	1.721	1.985
1000	2.289	2.321	2.354	2.387	2.422	2.493	2.566	2.643	2.798	–

Amagat, C. R. 111, 1890; 116, 1893.

TABLE 57.—Ethylene.

Pressure in metres of mercury.	Relative values of pv at —									
	16°.3	20°.3	30°.1	40°.0	50°.0	60°.0	70°.0	79°.9	89°.9	100°.0
30	1950	2055	2220	2410	2580	2715	2865	2970	3090	3225
60	810	900	1190	1535	1875	2100	2310	2500	2680	2860
90	1065	1115	1195	1325	1510	1710	1930	2160	2375	2565
120	1325	1370	1440	1540	1660	1780	1950	2115	2305	2470
150	1590	1625	1690	1785	1880	1990	2125	2250	2390	2540
180	1855	1890	1945	2035	2130	2225	2340	2450	2565	2700
210	2110	2145	2200	2285	2375	2470	2565	2680	2790	2910
240	2360	2395	2450	2540	2625	2720	2810	2910	3015	3125
270	2610	2640	2710	2790	2875	2965	3060	3150	3240	3345
300	2860	2890	2960	3040	3125	3215	3300	3380	3470	3560
320	3035	3065	3125	3200	3285	3375	3470	3545	3625	3710

Amagat, Ann. chim. phys. (6) 22, 1881.

COMPRESSIBILITY OF GASES.

TABLE 58. — Carbon Dioxide.

Pressure in metres of mercury.	Relative values of pv at —								
	18°.2	35°.1	40°.2	50°.0	60°.0	70°.0	80°.0	90°.0	100°.0
30	liquid	2360	2460	2590	2730	2870	2995	3120	3225
50	–	1725	1900	2145	2330	2525	2685	2845	2980
80	625	750	825	1200	1650	1975	2225	2440	2635
110	825	930	980	1090	1275	1550	1845	2105	2325
140	1020	1120	1175	1250	1360	1525	1715	1950	2160
170	1210	1310	1360	1430	1520	1645	1780	1975	2135
200	1405	1500	1550	1615	1705	1810	1930	2075	2215
230	1590	1690	1730	1800	1890	1990	2090	2210	2340
260	1770	1870	1920	1985	2070	2166	2265	2375	2490
290	1950	2060	2100	2170	2260	2340	2440	2550	2655
320	2135	2240	2280	2360	2440	2525	2620	2725	2830

Atm.	Relative values of pv; pv at 0° C. and 1 atm. = 1.										
	0°	10°	20°	30°	40°	60°	80°	100°	137°	198°	258°
50	0.105	0.114	0.680	0.775	0.750	0.984	1.096	1.206	1.380	–	–
100	0.202	0.213	0.229	0.255	0.309	0.661	0.873	1.030	1.259	1.582	1.847
150	0.295	0.309	0.326	0.346	0.377	0.485	0.681	0.878	1.159	1.530	1.818
300	0.559	0.578	0.599	0.623	0.649	0.710	0.790	0.890	1.108	1.493	1.820
500	0.891	0.913	0.938	0.963	0.990	1.054	1.124	1.201	1.362	1.678	–
1000	1.656	1.685	1.716	1.748	1.780	1.848	1.921	1.999	–	–	–

Amagat, C. R. 111, 1890; Ann chim. phys. (6) 29, 1893; 22, 1881.

TABLE 59. — Compressibility of Gases.

Gas.	$\frac{pv.\ (\frac{1}{4}\ \text{atm.})}{pv_0\ (1\ \text{atm.})}$	$\frac{1}{pv}\frac{d(pv)}{dp} = a.$	t	$\frac{a}{t=0}$	Density. O = 32, 0°C. P = 76cm	Density. Very small pressure.
O_2	1.00038	— .00076	11.2°	— .00094	32.	32.
H_2	0.99974	+ .00052	10.7	+ .00053	2.015 (16°)	2.0173
N_2	1.00015	— .00030	14.9	— .00056	28.005	28.016
CO	1.00026	— .00052	13.8	— .00081	28.000	28.003
CO_2	1.00279	— .00558	15.0	— .00668	44.268	44.014
N_2O	1.00327	— .00654	11.0	— .00747	44.285	43.996
Air	1.00026	— .00046	11.4	–	–	–
NH_3	1.00632	–	–	–	–	–

Rayleigh, Zeitschr. Phys. Chem. 52, 1905.

TABLE 60. — Compressibility of Air and Oxygen between 18° and 22° C.

Pressures in metres of mercury, pv, relative.

Air	p	24.07	34.90	45.24	55.30	64.00	72.16	84.22	101.47	214.54	304.04
	pv	26968	26908	26791	26789	26778	26792	26840	27041	29585	32488
O_2	p	24.07	34.89	–	55.50	64.07	72.15	84.19	101.06	214.52	303.03
	pv	26843	26614	–	26185	26050	25858	25745	25639	26536	28756

Amagat, C. R. 1879.

RELATION BETWEEN PRESSURE, TEMPERATURE AND VOLUME OF SULPHUR DIOXIDE AND AMMONIA.*

TABLE 61.—Sulphur Dioxide.

Original volume 100000 under one atmosphere of pressure and the temperature of the experiments as indicated at the top of the different columns.

Pressure in Atmos.	Corresponding Volume for Experiments at Temperature—			Volume.	Pressure in Atmospheres for Experiments at Temperature—		
	58°.0	99°.6	183°.2		58°.0	99°.6	183°.2
10	8560	9440	–				
12	6360	7800	–	10000	–	9.60	–
14	4040	6420	–	9000	9.60	10.35	–
16	–	5310	–	8000	10.40	11.85	–
18	–	4405	–	7000	11.55	13.05	–
20	–	4030	–	6000	12.30	14.70	–
24	–	3345	–	5000	13.15	16.70	–
28	–	2780	3180	4000	14.00	20.15	–
32	–	2305	2640	3500	14.40	23.00	–
36	–	1935	2260	3000	–	26.40	29.10
40	–	1450	2040	2500	–	30.15	33.25
50	–	–	1640	2000	–	35.20	40.95
60	–	–	1375	1500	–	39.60	55.20
70	–	–	1130	1000	–	–	76.00
80	–	–	930	500	–	–	117.20
90	–	–	790				
100	–	–	680				
120	–	–	545				
140	–	–	430				
160	–	–	325				

TABLE 62.—Ammonia.

Original volume 100000 under one atmosphere of pressure and the temperature of the experiments as indicated at the top of the different columns.

Pressure in Atmos.	Corresponding Volume for Experiments at Temperature—			Volume.	Pressure in Atmospheres for Experiments at Temperature—			
	46°.6	99°.6	183°.6		30°.2	46°.6	99°.6	183°.0
10	9500	–	–	10000	8.85	9.50		–
12.5	7245	7635	–	9000	9.60	10.45		–
15	5880	6305	–	8000	10.40	11.50	12.00	–
20	–	4645	4875	7000	11.05	13.00	13.60	–
25	–	3560	3835	6000	11.80	14.75	15.55	–
30	–	2875	3185	5000	12.00	16.60	18.60	19.50
35	–	2440	2680	4000	–	18.35	22.70	24.00
40	–	2080	2345	3500	–	18.30	25.40	27.20
45	–	1795	2035	3000	–	–	29.20	31.50
50	–	1490	1775	2500	–	–	34.25	37.35
55	–	1250	1590	2000	–	–	41.45	45.50
60	–	975	1450	1500	–	–	49.70	58.00
70	–	–	1245	1000	–	–	59.65	93.60
80	–	–	1125					
90	–	–	1035					
100	–	–	950					

* From the experiments of Roth, "Wied. Ann." vol. 11, 1880.

COMPRESSIBILITY OF LIQUIDS.

If V_1 is the volume under pressure p_1 atmospheres at $t°C$, and V_2 is volume at pressure p_2 and the same temperature, then the compressibility coefficient may be defined at that temperature as

$$\beta_t = \frac{1}{V_1} \cdot \frac{V_1 - V_2}{p_1 - p_2}.$$

In absolute units (referred to megadynes) the coefficient is $\frac{1}{1.0137}$.

Substance.	t.	Pressures.	$\beta \cdot 10^6$	Reference.
	°			
Acetone	0.00	1–500	82	1
"	0.00	500–1000	59	"
"	0.00	1000–1500	47	"
"	99.5	8.94–36.5	276	3
Benzole	5.95	8	83	2
"	17.9	8	92	"
"	15.4	1–4	87	4
"	78.8	1–4	126	"
Carbon bisulphide	0.00	1–500	66	1
" "	0.00	500–1000	53	"
" "	0.00	1000–1500	43	"
" "	49.2	1000–1500	51	"
Chloroform	0.	–	101	5
"	20.	–	128	"
"	40.	–	162	"
"	60.	–	204	"
"	100.	8–9	211	3
"	100.	19–34	206	"
Collodium	14.8		97	6
Ethyl alcohol	28.	150–200	86	7
" "	28.	150–400	81	"
" "	65.	150–200	110	"
" "	65.	150–400	100	"
" "	100.	150–200	168	"
" "	100.	150–400	132	"
" "	185.	150–200	320	"
" "	185.	150–400	245	"
" "	310.	150–200	4200	"
" "	310.	150–400	1530	"
" "	0.	1–50	96	1
" "	20.	1–50	112	"
" "	40.	1–50	125	"
" "	0.	100–200	85	"
" "	0.	300–400	73	"
" "	20.	300–400	78	"
" "	40.	300–400	87	"
" "	0.	500–600	64	"
" "	0.	700–800	56	"
" "	20.	700–800	62	"
" "	40.	700–800	65	"
" "	0.	900–1000	52	"
Ethyl chloride	11.	8.5–34.2	138	3
" "	15.2	8.7–37.2	153	"
" "	61.5	12.6–34.4	256	"
" "	99.0	12.8–34.5	495	"
Glycerine	20.5	–	25	8
"	14.8	–	22	6
Mercury	0.	–	3.92	9
"	0.	–	3.90	10
Methyl alcohol	14.7	8.50–37.1	104	3

Substance.	t.	Pressures.	$\beta \cdot 10^6$	Reference.
	°			
Methyl alcohol	100.	8.68–37.3	221	3
" "	18.10	8	120	2
Nitric acid	20.3	1–32	338	11
Oils: Almond	17.	–	55	8
Olive	20.5	–	63	"
Paraffin	14.8	–	63	6
Petroleum	16.5	–	70	12
Rock	19.4	–	75	8
Rape-seed	20.3	–	60	"
Turpentin	19.7	–	79	"
Toluene	10.	–	79	13
"	100.	–	150	"
Xylene	10.	–	74	"
"	100.	–	132	"
Paraffins: C_6H_{14}	23.	0–1	159	14
C_7H_{16}	"	"	134	"
C_8H_{18}	"	"	121	"
C_9H_{20}	"	"	113	"
$C_{10}H_{22}$	"	"	105	"
$C_{12}H_{26}$	"	"	92	"
$C_{14}H_{30}$	"	"	83	"
$C_{16}H_{34}$	"	"	75	"
Water	0.	1–25	525	1
"	10.	"	500	"
"	20.	"	491	"
"	0.	25–50	516	"
"	10.	"	492	"
"	20.	"	476	"
"	0.	1–100	511	"
"	10.	"	483	"
"	20.	"	468	"
"	50.	"	449	"
"	100.	"	478	"
"	0.	100–200	492	"
"	10.	"	461	"
"	20.	"	442	"
"	50.	"	425	"
"	100.	"	468	"
"	0.	1–500	475	"
"	20.4	"	434	"
"	48.85	"	416	"
"	0.	500–1000	416	"
"	0.	1000–1500	358	"
"	20.4	"	338	"
"	48.85	"	325	"
"	0.	1500–2000	324	"
"	0.	2000–2500	292	"
"	0.	2500–3000	261	"
"	48.85	"	254	"

For references see page 83.

COMPRESSIBILITY AND BULK MODULI OF SOLIDS.

Solid.	Compression per unit volume per atmo. × 10^6.	Authority.	Calculated values of bulk modulus in —	
			Grammes per sq. cm.	Pounds per sq. in.
Crystals: Barite	1.93	Voigt	535 × 10^6	7.61 × 10^6
Beryl	0.747	"	1384 "	19.68 "
Fluorspar	1.20	"	860 "	12.24 "
Pyrites	1.14	"	906 "	12.89 "
Quartz	2.67	"	387 "	5.50 "
Rock salt	4.20*	"	246 "	3.50 "
Sylvine	7.45*	"	138 "	1.97 "
Topaz	0.61	"	1694 "	24.11 "
Tourmaline	0.113	"	9140 "	130.10 "
Brass	0.95	Amagat	1090 "	15.48 "
Copper	0.86	Buchanan	1202 "	17.10 "
Delta metal	1.02	Amagat	1012 "	14.41 "
Lead	2.76	"	374 "	5.32 "
Steel	0.68	"	1518 "	21.61 "
Glass	2.2–2.9	"	405 "	5.76 "

NOTE: Winklemann, Schott, and Straulel (Wied Ann. 61, 63, 1897; 68, 1899) give the following coefficients (among others) for various Jena glasses in terms of the volume decrease divided by the increase of pressure expressed in kilogrammes per square millimetre:

No.	Glass.	Compressibility.	No.	Glass.	Compressibility.
665		7520	2154	Kalibleisilicat	3660
1299	Barytborosilicat	5800	S 208	Heaviest Bleisilicat	3550
16	Natronkalkzinksilicat	4530	500	Very heavy "	3510
278		3790	S 196	Tonerdborat with sodium, baryte	3470

* Röntgen and Schneider by piezometric experiments obtained 5.0 × 10^{-6} for rock salt, and 5.6 × 10^{-6} for sylvine (Wied. Ann., vol. 31).

References to Tables 63 and 64.

Liquids (Table 63):

1 Amagat, Ann. chim. phys. (6) 29, 1893.
2 Röntgen, Wied. Ann. 44, 1891.
3 Amagat, C. R. 68, 1869; (5) 28, 1883.
4 Pagliani-Palazzo, Mem. Acad. Lin. (3) 19, 1883.
5 Grimaldi, Zeitschr. Phys. Chem. 1, 1887.
6 de Metz, Wied. Ann. 41, 1890; 47, 1892.
7 Barus, Sill. Journ. 39, 1890; 41, 1891; Bull. U. S. Geol. Surv. 1892.
8 Quincke, Wied. Ann. 19, 1893.
9 Amagat, Ann. chim. phys. (6) 22, 1891.
10 Aimé, Ann. chim. phys. (3) 8, 1843.
11 Colladon-Sturm, Pogg. Ann. 12, 1828.
12 Martini.
13 de Heen, Bull. Acad. Roy. Belg. (3) 9, 1895.
14 Batelli, Phys. Zeitschr. 28, 29, 1896.

Solids (Table 64):

Amagat, C. R. 108, 1889; J. de Phys. (2) 8, 1889.
Buchanan, Proc. Roy. Soc. Edinb. 10, 1880.
Voigt, Wied. Ann. 31, 1887; 34, 1888; 36, 1888.

SPECIFIC GRAVITIES CORRESPONDING TO THE BEAUMÉ SCALE.

The specific gravities are for 15.56°C (60°F) referred to water at the same temperature as unity. For specific gravities less than unity the values are calculated from the formula:

$$\text{Degrees Beaumé} = 145 - \frac{145}{\text{Specific Gravity}}.$$

For specific gravities greater than unity from:

$$\text{Degrees Beaumé} = \frac{140}{\text{Specific Gravity}} - 130.$$

Specific Gravities less than 1.

Specific Gravity.	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
	Degrees Beaumé.									
0.60	103.33	99.51	95.81	92.22	88.75	85.38	82.12	78.95	75.88	72.90
.70	70.00	67.18	64.44	61.78	59.19	56.67	54.21	51.82	49.49	47.22
.80	45.00	42.84	40.73	38.68	36.67	34.71	32.79	30.92	29.09	27.30
.90	25.56	23.85	22.17	20.54	18.94	17.37	15.83	14.33	12.86	11.41
1.00	10.00									

Specific Gravities greater than 1.

Specific Gravity.	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
	Degrees Beaumé.									
1.00	0.00	1.44	2.84	4.22	5.58	6.91	8.21	9.49	10.74	11.97
1.10	13.18	14.37	15.54	16.68	17.81	18.91	20.00	21.07	22.12	23.15
1.20	24.17	25.16	26.15	27.11	28.06	29.00	29.92	30.83	31.72	32.60
1.30	33.46	34.31	35.15	35.98	36.79	37.59	38.38	39.16	39.93	40.68
1.40	41.43	42.16	42.89	43.60	44.31	45.00	45.68	46.36	47.03	47.68
1.50	48.33	48.97	49.60	50.23	50.84	51.45	52.05	52.64	53.23	53.80
1.60	54.38	54.94	55.49	56.04	56.58	57.12	57.65	58.17	58.69	59.20
1.70	59.71	60.20	60.70	61.18	61.67	62.14	62.61	63.08	63.54	63.99
1.80	64.44	64.89	65.33	65.76	66.20	66.62				

DENSITY OR MASS IN GRAMMES PER CUBIC CENTIMETRE AND POUNDS PER CUBIC FOOT OF THE ELEMENTS, LIQUID OR SOLID.

Element.	Physical State.	Grammes per cu. cm.	Pounds per cu. foot.	Temperature.*	Authority.
Aluminum	cast	2.56–2.58	160–161		
"	wrought	2.65–2.80	165–175		
"	pure	2.58	161	4	Mallet, 1882.
Antimony	vacuo-distilled	6.618	413.2	20	Kahlbaum, 1902.
"	ditto-compressed	6.691	417.7	20	"
"	amorphous	6.22	388		Hérard.
Argon	liquid	1.3845	86.43	—183	Baly-Donnan.
"	"	1.4233	88.86	—189	" "
Arsenic	crystallized	5.73	358	14	
"	amorph. br.-black	3.70	231		Geuther
"	yellow	3.88	242		Linck
Barium		3.75	234		
Beryllium		1.73–2.13	108–133		
Bismuth	solid	9.70–9.90	605–618		
"	electrolytic	9.747	608.5		Classen, 1890.
"	vacuo-distilled	9.781	610.6	20	Kahlbaum, 1902.
"	liquid	10.00	624	271	Vincentini-Omodei.
"	solid	9.67	604	271	" "
Boron	crystal	2.5–2.6	156–162		
"	amorph. pure	2.45	153		Moissan
Bromine	liquid	3.15	197		
Cadmium	cast	8.54–8.57	5.33–5.35		
"	wrought	8.67	541		
"	vacuo-distilled	8.648	539.9	20	Kahlbaum, 1902.
"	solid	8.37	522	318	Vincentini-Omodei.
"	liquid	7.99	498	318	" "
Cæsium		1.88	117		
Calcium		1.52	95		Arndt, Ch. Ber. 1904.
Carbon	diamond	3.47–3.56	216–222		Liversidge.
"	graphite	2.10–2.32	131–145		
Cerium	electrolytic	6.79	424		Muthmann-Weiss
"	pure	7.02	438		" "
Chlorine	liquid	1.507	94.1	—33.6	Drugman-Ramsay
Chromium		6.52–6.73	407–420		
"	pure	6.92	432	20	Moissan.
Cobalt		8.71	544	21	Tilden, Ch. C. 1898.
Columbium	liquid	7.1–7.4	440–460		
Copper	cast	8.80–8.95	549–558		
"	drawn	8.93–8.95	557–558		
"	wrought	8.85–8.95	552–558		
"	electrolytic	8.88–8.95	554–558		
"	vacuo-distilled	8.9326	557.7	20	Kahlbaum, 1902.
"	ditto-compressed	8.9376	558.0	20	" "
"	liquid	8.217	513		Roberts-Wrightson.
Erbium		4.77	298		St. Meyer, Z. Ph. Ch. 37.
Fluorine	liquid	1.14	71	—200	Moissan-Dewar.
Gallium		5.93	370	23	de Boisbaudran.
Germanium		5.46	341	20	Wimkler.
Glucinium		1.86–2.06	116–127		
Gold	cast	19.3	1200		
"	wrought	19.33	1207		
"	vacuo-distilled	18.88	1178	20	Kahlbaum, 1902.
"	ditto-compressed	19.27	1202	20	"
Hydrogen	liquid	0.070	4.3	—252	Dewar, Ch. News, 1904.
Indium		7.12–7.42	444–463		

* Where the temperature is not given, ordinary atmospheric temperature is understood.

Compiled from Clarke's Constants of Nature, Landolt-Börnstein-Meyerhoffer's Tables, and other sources. Where no authority is stated, the values are mostly means from various sources.

DENSITY OR MASS IN GRAMMES PER CUBIC CENTIMETRE AND POUNDS PER CUBIC FOOT OF THE ELEMENTS, LIQUID OR SOLID.

Element.	Physical State.	Grammes per cu. cm.	Pounds per cu. foot.	Temperature.*	Authority.
Iridium		22.42	1399	17	Deville-Debray
Iodine		4.7–4.9	293–306	17	
Iron	pure	7.63–7.88	490–492		
"	gray cast	7.03–7.13	439–445		
"	white cast	7.58–7.73	473–482		
"	wrought	7.80–7.90	487–492		
"	liquid	6.88	429		Roberts-Austen
"	steel	7.60–7.80	474–487		
Lanthanum		6.15	384		Muthmann-Weiss
Lead	cast	11.37	710	24	Reich
"	wrought	11.36	709	24	"
"	solid	11.005	686	325	Vincentini-Omodei
"	liquid	10.645	664	325	" "
"	vacuo-distilled	11.342	708.1	20	Kahlbaum, 1902
"	ditto-compressed	11.347	708.4	20	" "
Lithium		0.534	33.3	20	Richards-Brink, '07
Magnesium		1.69–1.75	105–109		
Manganese		7.4	460		
Mercury	liquid	13.596	848.8	0	Regnault, Volkmann
"	"	13.546	845.7	20	
"	"	13.690	854.7	—38.8	Vincentini-Omodei
"	solid	14.193	886.1	—38.8	Mallet
"	"	14.383	897.9	—188	Dewar, 1902
Molybdenum		8.4–8.6	520–540		
Nickel		8.60–8.90	540–550		
Niobium		7.2	450		
Nitrogen	liquid	0.810	50.5	—195	Baly-Donnan, 1902
"	"	0.854	53.3	—205	" " "
Osmium		22.5	1400		
Oxygen	liquid	1.14	71	184	
Palladium		11.4	711		
Phosphorus	white	1.83	114		
"	red	2.20	137		
"	metallic	2.34	146	15	Hittorf
Platinum		21.2–21.7	1320–1350		
Potassium		0.86–0.88	54–55		
"	solid	0.851	53.7	62.1	Vincentini-Omodei
"	liquid	0.830	53.8	62.1	" "
Præsodymium		6.475	404		Muthmann-Weiss
Rhodium		11.0–12.1	686–755		
Rubidium		1.532	95.6	20	Richards-Brink, '07
Ruthenium		12.3	768		
Samarium		7.7–7.8	480–490		Muthmann-Weiss
Selenium		4.3–4.8	270–300		
Silicon		2.0–2.4	120–150		
Silver	cast	10.42–10.53	650–657		
"	wrought	10.6	661		
"	vacuo-distilled	10.492	655.0	20	Kahlbaum, 1902
"	ditto-compressed	10.503	655.7	20	" "
"	liquid	9.51	593		Roberts-Austen
Sodium		0.9712	60.63	20	Richards-Brink, '07
"	solid	0.9519	59.4	97.6	Vincentini-Omodei
"	liquid	0.9287	58.0	97.6	" "
"		1.0066	62.84	—188	Dewar
Strontium		2.50–2.58	156–161		Matthiessen
Sulphur		2.0–2.1	120–130		
"	liquid	1.811	113.1	113	Vincentini-Omodei

* Where the temperature is not given, ordinary atmospheric temperature is understood.

TABLE 66 (*continued*). — Density or Mass in grammes per cubic centimetre and pounds per cubic foot of the elements, liquid or solid.

Element.	Physical State.	Grammes per cu. cm.	Pounds per cu. foot.	Temperature.*	Authority.
Tantalum		10.4–12.8	650–800		
Tellurium	crystallized	6.25	390		
"	amorphous	6.02	376	20	Beljankin.
Thallium		11.8–11.9	736–742		
Thorium		11.0	690	17	Nilson.
Tin	white, cast	7.29	455		Matthiessen.
"	" wrought	7.30	455		
"	" crystallized	6.97–7.18	435–448		
"	" solid	7.184	454	226	Vincentini-Omodei.
"	" liquid	6.99	436		
"	gray	5.8	360		
Titanium		3.5	220		
Tungsten		18.6–19.1	1160–1190		
Uranium		18.7	1170	13	Zimmermann.
Vanadium		5.5	340		Roscoe.
Xenon	liquid	3.52	220		Ramsay-Travers.
Yttrium		3.8	240		St. Meyer.
Zinc	cast	7.04–7.16	439–447		
"	wrought	7.19	449		
"	vacuo-distilled	6.92	432	20	Kahlbaum, 1902.
"	ditto-compressed	7.13	445	20	" "
"	liquid	6.48	404		Roberts-Wrightson.
Zirconium		4.14	258		Froost.

TABLE 67 — Mass in grammes per cubic centimetre and in pounds per cubic foot of different kinds of wood.

The wood is supposed to be seasoned and of average dryness.

Wood.	Grammes per cubic centimetre.	Pounds per cubic foot.	Wood.	Grammes per cubic centimetre.	Pounds per cubic foot.
Alder	0.42–0.68	26–42	Hazel	0.60–0.80	37–49
Apple	0.66–0.84	41–52	Hickory	0.60–0.93	37–58
Ash	0.65–0.85	40–53	Holly	0.76	47
Bamboo	0.31–0.40	19–25	Iron-bark	1.03	64
Basswood. See Linden.			Juniper	0.56	35
Beech	0.70–0.90	43–56	Laburnum	0.92	57
Blue gum	1.00	52	Lancewood	0.68–1.00	42–62
Birch	0.51–0.77	32–48	Lignum vitæ	1.17–1.33	73–83
Box	0.95–1.16	59–72	Linden or Lime-tree	0.32–0.59	20–37
Bullet-tree	1.05	65	Locust	0.67–0.71	42–44
Butternut	0.38	24	Logwood	.91	57
Cedar	0.49–0.57	30–35	Mahogany, Honduras	0.66	35
Cherry	0.70–0.90	43–56	" Spanish	0.85	53
Cork	0.22–0.26	14–16	Maple	0.62–0.75	39–47
Dogwood	0.76	47	Oak	0.60–0.90	37–56
Ebony	1.11–1.33	69–83	Pear-tree	0.61–0.73	38–45
Elm	0.54–0.60	34–37	Plum-tree	0.66–0.78	41–49
Fir or Pine, American White	0.35–0.50	22–31	Poplar	0.35–0.5	22–31
" Larch	0.50–0.56	31–35	Satinwood	0.95	59
" Pitch	0.83–0.85	52–53	Sycamore	0.40–0.60	24–37
" Red	0.48–0.70	30–44	Teak, Indian	0.66–0.88	41–55
" Scotch	0.43–0.53	27–33	" African	0.98	61
" Spruce	0.48–0.70	30–44	Walnut	0.64–0.70	40–43
" Yellow	0.37–0.60	23–37	Water gum	1.00	62
Greenheart	0.93–1.04	58–65	Willow	0.40–0.60	24–37

* Where the temperature is not given, ordinary atmospheric temperature is understood.

TABLE 68.

DENSITY OR MASS IN GRAMMES PER CUBIC CENTIMETRE AND POUNDS PER CUBIC FOOT OF VARIOUS SOLIDS.*

Substance.	Grammes per cubic centimetre.	Pounds per cubic foot.
Agate	2.5–2.7	156–168
Alabaster:		
Carbonate	2.69–2.78	168–173
Sulphate	2.26–2.32	141–145
Alum, potash	1.75	109
Amber	1.06–1.11	66–69
Anthracite	1.4–1.8	87–112
Apatite	3.16–3.22	197–201
Aragonite	3.0	187
Arsenic	5.7–5.72	356–358
Asbestos	2.0–2.8	125–175
Asphaltum	1.1–1.5	69–94
Barite	4.5	281
Basalt	2.4–3.1	150–193
Beeswax	0.96–0.97	60–61
Bole	2.2–2.5	137–156
Bone	1.7–2.0	106–125
Boracite	2.9–3.0	181–187
Borax	1.7–1.8	106–112
Borax glass	2.6	162
Boron	2.45–2.69	153–168
Brick	1.4–2.2	87–137
Butter	0.86–0.87	53–54
Calamine	4.1–4.5	255–280
Calcspar	2.6–2.8	162–175
Carbon.		
See Graphite, etc.		
Caoutchouc	0.92–0.99	57–62
Celestine	3.9	243
Cement:		
Pulverized loose	1.15–1.7	72–105
Pressed	1.85	115
Set	2.7–3.0	168–187
Cetin	0.88–0.94	55–59
Chalk	1.9–2.8	118–175
Charcoal:		
Oak	0.57	35
Pine	0.28–0.44	17.5–27.5
Chrome yellow	6.00	374
Cinnabar	8.12	507
Clay	1.8–2.6	122–162
Clayslate	2.8–2.9	175–180
Coal, soft	1.2–1.5	75–94
Cobaltite	6.4–7.3	400–455
Cocoa butter	0.89–0.91	56–57
Coke	1.0–1.7	62–105
Copal	1.04–1.14	65–71
Corundum	3.9–4.0	245–250
Diamond	3.5–3.6	220–225
Anthracitic	1.66	104
Carbonado	3.01–3.25	188–203
Diorite	2.8–3.1	175–193
Dolomite	2.4–2.9	150–181
Earth, dry	1.6–1.9	100–120
Ebonite	1.15	72
Emery	4.0	250
Epsom salts:		
Crystalline	1.7–1.8	106–112
Anhydrous	2.6	162
Feldspar	2.53–2.58	158–161
Flint	2.63	164
Fluor spar	3.14–3.18	196–198
Gabronite	2.9–3.0	181–187
Gamboge	1.2	75
[illegible]ena	7.3–7.6	460–470
Garnet	3.6–3.8	230–335
Gas carbon	1.88	119
Glass:		
Common	2.4–2.8	150–175
Flint	2.9–5.9	180–370
Glauber's salt	1.4–1.5	87–93
Glue	1.27	80
Gneiss	2.4–3.2	150–200
Granite	2.0–3.0	125–187
Graphite	1.9–2.3	120–140
Gravel	1.2–1.8	94–112
Gray copper ore	4.4–5.4	275–335
Green stone	2.9–3.0	180–185
Gum arabic	1.3–1.4	80–85
Gunpowder:		
Loose	0.9	56
Tamped	1.75	109
Gypsum, burnt	1.81	113
Hornblende	3.0	187
Ice	0.88–0.91	55–57
Iodine	4.67	291
Ivory	1.83–1.92	114–120
Kaolin	2.2	137
Lava:		
Basaltic	2.8–3.0	175–185
Trachytic	2.0–2.7	125–168
Lead acetate	2.4	150
Leather:		
Dry	0.86	54
Greased	1.02	64
Lime:		
Mortar	1.65–1.78	103–111
Slaked	1.3–1.4	81–87
Lime	2.3–3.2	144–200
Limestone	2.0–3.1	125–190
Litharge:		
Artificial	9.3–9.4	580–585
Natural	7.8–8.0	489–492
Magnesia	3.2	200
Magnesite	3.0	187
Magnetite	4.9–5.2	306–324
Malachite	3.7–4.1	231–256
Manganese:		
Red ore	3.46	216
Black ore	3.9–4.1	243–256
Marble	2.5–2.8	157–177
Marl	1.6–2.5	100–156
Masonry	1.85–2.3	116–144
Meerschaum	.99–1.28	61.8–79.9
Melaphyre	2.6	162
Mica	2.6–3.2	165–200
Mortar	1.75	109
Mud	1.6	102
Nitroglycerine	1.6	99
Ochre	3.5	218
Opal	2.2	137
Orpiment	3.4–3.5	212–218
Paper	0.7–1.15	44–72
Paraffin	0.87–0.91	54–57
Peat	0.84	52
Phosphorus, white	1.82	114
Pitch	1.07	67
Porcelain	2.3–2.5	143–156
Porphyry	2.6–2.9	162–181
Potash	2.26	141

* For elements, see Table 66.

TABLE 68 (*continued*).—Density of Various Solids.

Substance.	Grammes per cubic centimetre.	Pounds per cubic foot.	Substance.	Grammes per cubic centimetre.	Pounds per cubic foot.
Pyrites	4.9–5.2	306–324	Snow, loose	0.125	7.8
Pyrolusite	3.7–4.6	231–287	Soapstone, Steatite	2.6–2.8	162–175
Pumice stone	0.37–0.9	23–56	Soda:		
Quartz	2.65	165	Roasted	2.5	156
Resin	1.07	67	Crystalline	1.45	90
Rock crystal	2.6	162	Spathic iron ore	3.7–3.9	231–243
Rock salt	2.28–2.41	142–150	Starch	1.53	95
Sal ammoniac	1.5–1.6	94–100	Stibnite	4.6–4.7	287–293
Saltpetre	1.95–2.08	122–130	Strontianite	3.7	231
Sand:			Syenite	2.1–3.0	130–190
Dry	1.40–1.65	87–103	Sugar	1.61	100
Damp	1.90–2.05	119–128	Talc	2.7	168
Sandstone	2.0–3.2	124–200	Tallow	0.91–0.97	570–605
Selenium	4.2–4.8	262–300	Tellurium	6.38–6.42	398–401
Serpentine	2.43–2.66	152–166	Tile	1.4–2.3	87–143
Shale	2.6	162	Tinstone	6.4–7.0	399–437
Silicon	2.0–2.5	125–156	Topaz	3.5–3.6	219–223
Siliceous earth	2.66	166	Tourmaline	2.94–3.24	183–202
Slag, furnace	2.0–3.9	124–240	Trachyte	2.7–2.8	168–175
Slate	2.6–3.3	162–205	Trap	2.6–2.7	162–170

TABLE 69.—Density or Mass in Grammes per Cubic Centimetre and Pounds per Cubic Foot of Various Alloys (Brasses and Bronzes).

Alloy.	Grammes per cubic centimetre.	Pounds per cubic foot.
Brasses: Yellow, 70Cu + 30Zn, cast	8.44	527
" " " rolled	8.56	534
" " " drawn	8.70	542
" Red, 90Cu + 10Zn	8.60	536
" White, 50Cu + 50Zn	8.20	511
Bronzes: 90Cu + 10Sn	8.78	548
" 85Cu + 15Sn	8.89	555
" 80Cu + 20Sn	8.74	545
" 75Cu + 25Sn	8.83	551
German Silver: Chinese, 26.3Cu + 36.6Zn + 36.8 Ni	8.30	518
" " Berlin (1) 52Cu + 26Zn + 22Ni	8.45	527
" " " (2) 59Cu + 30Zn + 11Ni	8.34	520
" " " (3) 63Cu + 30Zn + 6Ni	8.30	518
" " Nickelin	8.77	547
Lead and Tin: 87.5Pb + 12.5Sn	10.60	661
" " " 84Pb + 16Sn	10.33	644
" " " 77.8Pb + 22.2Sn	10.05	627
" " " 63.7Pb + 36.3Sn	9.43	588
" " " 46.7Pb + 53.3Sn	8.73	545
" " " 30.5Pb + 69.5Sn	8.24	514
Bismuth, Lead, and Tin: 53Bi + 40Pb + 7Cd	10.56	659
Wood's Metal: 50Bi + 25Pb + 12.5Cd + 12.5Sn	9.70	605
Cadmium and Tin: 32Cd + 68Sn	7.70	480
Gold and Copper: 98Au + 2Cu	18.84	1176
" " " 96Au + 4Cu	18.36	1145
" " " 94Au + 6Cu	17.95	1120
" " " 92Au + 8Cu	17.52	1093
" " " 90Au + 10Cu	17.16	1071
" " " 88Au + 12Cu	16.81	1049
" " " 86Au + 14Cu	16.47	1027
Aluminum and Copper: 10Al + 90Cu	7.69	480
" " " 5Al + 95Cu	8.37	522
" " " 3Al + 97Cu	8.69	542
Aluminum and Zinc: 91Al + 9Zn	2.80	175
Platinum and Iridium: 90Pt + 10Ir	21.62	1348
" " " 85Pt + 15Ir	21.62	1348
" " " 66.67Pt + 33.33Ir	21.87	1364
" " " 5Pt + 95Ir	22.38	1396

DENSITY OF LIQUIDS.

Density or mass in grammes per cubic centimetre and in pounds per cubic foot of various liquids.

Liquid.	Grammes per cubic centimetre.	Pounds per cubic foot	Temp. C.
Acetone	0.792	49.4	0°
Alcohol, ethyl	0.791	49.4	0
" methyl	0.810	50.5	0
" proof spirit	0.916	57.2	0
Anilin	1.035	64.5	0
Benzene	0.899	56.1	0
Bromine	3.187	199.0	0
Carbolic acid (crude)	0.950–0.965	59.2–60.2	15
Carbon disulphide	1.293	80.6	15
Chloroform	1.480	92.3	18
Ether	0.736	45.9	0
Gasoline	0.66–0.69	41.0–43.0	–
Glycerine	1.260	78.6	0
Milk	1.028–1.035	64.2–64.6	–
Naphtha (wood)	0.848–0.810	52.9–50.5	0
Naphtha (petroleum ether)	0.665	41.5	15
Oils: Amber	0.800	49.9	15
Anise-seed	0.996	61.1	16
Camphor	0.910	56.8	–
Castor	0.969	60.5	15
Cocoanut	0.925	57.7	15
Cotton seed	0.926	60.2	16
Creosote	1.040–1.100	64.9–68.6	15
Lard	0.920	57.4	15
Lavender	0.877	54.7	16
Lemon	0.844	52.7	16
Linseed (boiled)	0.942	58.8	15
Mineral (lubricating)	0.900–0.925	56.2–57.7	20
Olive	0.918	57.3	15
Palm	0.905	56.5	15
Pine	0.850–0.860	53.0–54.0	15
Poppy	0.924	57.7	–
Rapeseed (crude)	0.915	57.1	15
" (refined)	0.913	57.0	15
Resin	0.955	59.6	15
Train *or* Whale	0.918–0.925	57.3–57.7	15
Turpentine	0.873	54.2	16
Valerian	0.965	60.2	16
Petroleum	0.878	54.8	0
" (light)	0.795–0.805	49.6–50.2	15
Pyroligneous acid	0.800	49.9	0
Sea water	1.025	64.0	15
Soda lye	1.210	75.5	17
Water	1.000	62.4	4

DENSITY OF GASES.

The following table gives the density of the gases at 0° C, 76 cm. pressure, at sea-level and latitude 45° relative to air as unity and under the same conditions; also the weight of one litre in grammes and one cubic foot in pounds.

Gas.	Specific Gravity.	Grammes per litre.	Pounds per cubic foot.	Reference.
Air	1.000	1.2928	.08071	Rayleigh; Leduc.
Acetylene	0.92	1.1620	.07254	Berthelot, 1860.
Ammonia	0.597	0.7621	.04758	Leduc, C. R. 125, 1897.
Argon	1.379	1.782	.1112	Ramsey-Travers, Proc. R. Soc. 67, 1900.
Bromine	5.524	7.1426	.4459	Jahn, 1882.
Butane	2.01	2.594	.16194	Frankland, Ann. Ch. Pharm. 71.
Carbon dioxide	1.5291	1.9652	.12269	Rayleigh, Proc. R. Soc. 62, 1897.
" monoxide	0.9672	1.2506	.07807	" " " " "
Chlorine	2.491	3.1666	.19769	Leduc, C. R. 125, 1897.
Coal gas { from	0.320	0.414	.02583	
Coal gas { to	0.740	0.957	.05973	
Cyanogen	1.806	2.3261	.14522	Gay-Lussac.
Ethane	1.075	1.3421	.08379	Kolbe, Ann. Chem. Pharm. 65.
Fluorine	1.26	1.697	.1059	Moissan, C. R. 109.
Helium	1.368	0.1787	.01116	Ramsey-Travers, Proc. R. Soc. 67, 1900.
Hydrofluoric acid	0.7126	0.894	.05581	Thorpe-Hambley, J. Chem. Soc. 53.
Hydrobromic acid	2.71	3.6163	.2258	Löwig, Gmelin-Kraut, Org. Chem.
Hydrochloric acid	1.2692	1.6283	.10165	Leduc, C. R. 125, 1897.
Hydrogen	0.0696	0.09004	.005621	Rayleigh, Proc. R. Soc. 53, 1893.
Hydrogen sulphide	1.1895	1.5230	.09508	Leduc, C. R. 125, 1897.
Krypton	2.818	3.654	.2281	Ramsey-Travers, Proc. R. Soc. 67, 1900.
Methane	0.5576	0.7160	.04470	Thomson.
Neon	0.674	0.893	.0558	Ramsey-Travers, Proc. R. Soc. 67, 1900.
Nitrogen	0.9673	1.2542	.07829	Rayleigh, Proc. R. Soc. 62, 1897.
Nitric oxide, NO	1.0387	1.3417	.08376	Leduc, C. R. 116, 1893.
Nitrous oxide, N_2O	1.5301	1.9688	.12291	" C. R. 125, 1897.
Oxygen	1.053	1.4292	.08922	Rayleigh, Proc. R. Soc. 62, 1897.
Sulphur dioxide	2.2639	2.8611	.17862	Leduc, C. R. 117, 1893.
Steam at 100°	0.469	0.581	.0363	
Xenon	4.422	5.717	.3569	Ramsey-Travers, Proc. R. Soc. 67, 1900.

Compiled partly from Landolt-Börnstein-Meyerhoffer's Physikalisch-Chemische Tabellen.

TABLE 72.*

DENSITY OF AQUEOUS SOLUTIONS.*

The following table gives the density of solutions of various salts in water. The numbers give the weight in grammes per cubic centimetre. For brevity the substance is indicated by formula only.

Substance.	Weight of the dissolved substance in 100 parts by weight of the solution.									Temp. C.	Authority.
	5	10	15	20	25	30	40	50	60		
K_2O	1.047	1.098	1.153	1.214	1.284	1.354	1.503	1.659	1.809	15.	Schiff.
KOH	1.040	1.082	1.027	1.076	1.229	1.286	1.410	1.538	1.666	15.	"
Na_2O	1.073	1.144	1.218	1.284	1.354	1.421	1.557	1.689	1.829	15.	"
NaOH	1.058	1.114	1.169	1.224	1.279	1.331	1.436	1.539	1.642	15.	"
NH_3	0.978	0.959	0.940	0.924	0.909	0.896	–	–	–	16.	Carius.
NH_4Cl	1.015	1.030	1.044	1.058	1.072	–	–	–	–	15.	Gerlach.
KCl	1.031	1.065	1.099	1.135	–	–	–	–	–	15.	"
NaCl	1.035	1.072	1.110	1.150	1.191	–	–	–	–	15.	"
LiCl	1.029	1.057	1.085	1.116	1.147	1.181	1.255	–	–	15.	"
$CaCl_2$	1.041	1.086	1.132	1.181	1.232	1.286	1.402	–	–	15.	"
$CaCl_2 + 6H_2O$	1.019	1.040	1.061	1.083	1.105	1.128	1.176	1.225	1.276	18.	Schiff.
$AlCl_3$	1.035	1.072	1.111	1.153	1.196	1.241	1.340	–	–	15.	Gerlach.
$MgCl_2$	1.041	1.085	1.130	1.177	1.226	1.278	–	–	–	15.	"
$MgCl_2 + 6H_2O$	1.014	1.032	1.049	1.067	1.085	1.103	1.141	1.183	1.222	24.	Schiff.
$ZnCl_2$	1.043	1.089	1.135	1.184	1.236	1.289	1.417	1.563	1.737	19.5	Kremers.
$CdCl_2$	1.043	1.087	1.138	1.193	1.254	1.319	1.469	1.653	1.887	19.5	"
$SrCl_2$	1.044	1.092	1.143	1.198	1.257	1.321	–	–	–	15.	Gerlach.
$SrCl_2 + 6H_2O$	1.027	1.053	1.082	1.111	1.042	1.174	1.242	1.317	–	15.	"
$BaCl_2$	1.045	1.094	1.147	1.205	1.269	–	–	–	–	15.	"
$BaCl_2 + 2H_2O$	1.035	1.075	1.119	1.166	1.217	1.273	–	–	–	21.	Schiff.
$CuCl_2$	1.044	1.091	1.155	1.221	1.291	1.360	1.527	–	–	17.5	Franz.
NCl_2	1.048	1.098	1.157	1.223	1.299	–	–	–	–	17.5	"
$HgCl_2$	1.041	1.092	–	–	–	–	–	–	–	20.	Mendelejeff.
Fe_2Cl_6	1.041	1.086	1.130	1.179	1.232	1.290	1.413	1.545	1.668	17.5	Hager.
$PtCl_4$	1.046	1.097	1.153	1.214	1.285	1.362	1.546	1.785	–	–	Precht.
$SnCl_2 + 2H_2O$	1.032	1.067	1.104	1.143	1.185	1.229	1.329	1.444	1.580	15.	Gerlach.
$SnCl_4 + 5H_2O$	1.029	1.058	1.089	1.122	1.157	1.193	1.274	1.365	1.467	15.	"
LiBr	1.033	1.070	1.111	1.154	1.202	1.252	1.366	1.498	–	19.5	Kremers.
KBr	1.035	1.073	1.114	1.157	1.205	1.254	1.364	–	–	19.5	"
NaBr	1.038	1.078	1.123	1.172	1.224	1.279	1.408	1.563	–	19.5	"
$MgBr_2$	1.041	1.085	1.135	1.189	1.245	1.308	1.449	1.623	–	19.5	"
$ZnBr_2$	1.043	1.091	1.194	1.202	1.263	1.328	1.473	1.648	1.873	19.5	"
$CdBr_2$	1.041	1.088	1.139	1.197	1.258	1.324	1.479	1.678	–	19.5	"
$CaBr_2$	1.042	1.087	1.137	1.192	2.250	1.313	1.459	1.639	–	19.5	"
$BaBr_2$	1.043	1.090	1.142	1.199	1.260	1.327	1.483	1.683	–	19.5	"
$SrBr_2$	1.043	1.089	1.140	1.198	1.260	1.328	1.489	1.693	1.953	19.5	"
KI	1.036	1.076	1.118	1.164	1.216	1.269	1.394	1.544	1.732	19.5	"
LiI	1.036	1.077	1.122	1.170	1.222	1.278	1.412	1.573	1.775	19.5	"
NaI	1.038	1.080	1.126	1.177	1.232	1.292	1.430	1.598	1.808	19.5	"
ZnI_2	1.043	1.089	1.138	1.194	1.253	1.366	1.418	1.648	1.873	19.5	"
CdI_2	1.042	1.086	1.136	1.192	1.251	1.317	1.474	1.678	–	19.5	"
MgI_2	1.041	1.086	1.137	1.192	1.252	1.318	1.472	1.666	1.913	19.5	"
CaI_2	1.042	1.088	1.138	1.196	1.258	1.319	1.475	1.663	1.908	19.5	"
SrI_2	1.043	1.089	1.140	1.198	1.260	1.328	1.489	1.693	1.953	19.5	"
BaI_2	1.043	1.089	1.141	1.199	1.263	1.331	1.493	1.702	1.968	19.5	"
$NaClO_3$	1.035	1.068	1.106	1.145	1.188	1.233	1.329	–	–	19.5	"
$NaBrO_3$	1.039	1.081	1.127	1.176	1.229	1.287	–	–	–	19.5	"
KNO_3	1.031	1.064	1.099	1.135	–	–	–	–	–	15.	Gerlach.
$NaNO_3$	1.031	1.065	1.101	1.140	1.180	1.222	1.313	1.416	–	20.2	Schiff.
$AgNO_3$	1.044	1.090	1.140	1.195	1.255	1.322	1.479	1.675	1.918	15.	Kohlrausch.

* *Compiled from two papers* on the subject by Gerlach in the "Zeit. für Anal. Chim.," vols. 8 and 27.

TABLE 72 (*continued*).

DENSITY OF AQUEOUS SOLUTIONS.

Substance.	Weight of the dissolved substance in 100 parts by weight of the solution.									Temp. C.	Authority.
	5	10	15	20	25	30	40	50	60		
NH_4NO_3 . . .	1.020	1.041	1.063	1.085	1.107	1.131	1.178	1.229	1.282	17.5	Gerlach.
$ZnNO_3$	1.048	1.095	1.146	1.201	1.263	1.325	1.456	1.597	–	17.5	Franz.
$ZnNO_3+6H_2O$.	–	1.054	–	1.113	–	1.178	1.250	1.329	–	14.	Oudemans.
$Ca(NO_3)_2$ . . .	1.037	1.075	1.118	1.162	1.211	1.260	1.367	1.482	1.604	17.5	Gerlach.
$Cu(NO_3)_2$ . . .	1.044	1.093	1.143	1.203	1.263	1.328	1.471	–	–	17.5	Franz.
$Sr(NO_3)_2$ . . .	1.039	1.083	1.129	1.179	–	–	–	–	–	19.5	Kremers.
$Pb(NO_3)_2$ . . .	1.043	1.091	1.143	1.199	1.262	1.332	–	–	–	17.5	Gerlach.
$Cd(NO_3)_2$ . . .	1.052	1.097	1.150	1.212	1.283	1.355	1.536	1.759	–	17.5	Franz.
$Co(NO_3)_2$ . . .	1.045	1.090	1.137	1.192	1.252	1.318	1.465	–	–	17.5	"
$Ni(NO_3)_2$ . . .	1.045	1.090	1.137	1.192	1.252	1.318	1.465	–	–	17.5	"
$Fe_2(NO_3)_6$ . . .	1.039	1.076	1.117	1.160	1.210	1.261	1.373	1.496	1.657	17.5	"
$Mg(NO_3)_2+6H_2O$	1.018	1.038	1.060	1.082	1.105	1.129	1.179	1.232	–	21	Schiff.
$Mn(NO_3)_2+6H_2O$	1.025	1.052	1.079	1.108	1.138	1.169	1.235	1.307	1.386	8	Oudemans.
K_2CO_3	1.044	1.092	1.141	1.192	1.245	1.300	1.417	1.543	–	15	Gerlach.
$K_2CO_3+2H_2O$.	1.037	1.072	1.110	1.150	1.191	1.233	1.320	1.415	1.511	15.	"
$Na_2CO_3 10H_2O$.	1.019	1.038	1.057	1.077	1.098	1.118	–	–	–	15.	"
$(NH_4)_2SO_4$ . .	1.027	1.055	1.084	1.113	1.142	1.170	1.226	1.287	–	19.	Schiff.
$Fe_2(SO_4)_3$ . . .	1.045	1.096	1.150	1.207	1.270	1.336	1.489	–	–	18.	Hager.
$FeSO_4+7H_2O$.	1.025	1.053	1.081	1.111	1.141	1.173	1.238	–	–	17.2	Schiff.
$MgSO_4$	1.051	1.104	1.161	1.221	1.284	–	–	–	–	15	Gerlach.
$MgSO+7H_2O$.	1.025	1.050	1.075	1.101	1.129	1.155	1.215	1.278	–	15.	"
$Na_2So_4+10H_2O$	1.019	1.039	1.059	1.081	1.102	1.124	–	–	–	15.	"
$CuSO_4+5H_2O$.	1.031	1.064	1.098	1.134	1.173	1.213	–	–	–	18.	Schiff.
$MnSO_4+4H_2O$.	1.031	1.064	1.099	1.135	1.174	1.214	1.303	1.398	–	15.	Gerlach.
$ZnSO_4+7H_2O$.	1.027	1.057	1.089	1.122	1.156	1.191	1.269	1.351	1.443	20.5	Schiff.
$Fe_2(SO)_3+K_2SO_4$ $+24H_2O$ . . .	1.026	1.045	1.066	1.088	1.112	1.141	–	–	–	17.5	Franz.
$Cr_2(SO)_3+K_2SO_4$ $+24H_2O$ . .	1.016	1.033	1.051	1.073	1.099	1.126	1.188	1.287	1.454	17.5	"
$MgSO_4+K_2SO_4$ $+6H_2O$ . . .	1.032	1.066	1.101	1.138	–	–	–	–	–	15.	Schiff.
$(NH_4)_2SO_4+$ $FeSO_4+6H_2O$	1.028	1.058	1.090	1.122	1.154	1.191	–	–	–	19.	"
K_2CrO_4	1.039	1.082	1.127	1.174	1.225	1.279	1.397	–	–	19.5	"
$K_2Cr_2O_7$ . . .	1.035	1.071	1.108	–	–	–	–	–	–	19.5	Kremers.
$Fe(Cy)_6K_4$ . . .	1.028	1.059	1.092	1.126	–	–	–	–	–	15.	Schiff.
$Fe(Cy)_6K_3$ . . .	1.025	1.053	1.145	1.179	–	–	–	–	–	13	"
$Pb(C_2H_3O_2)_2+$ $3H_2O$	1.031	1.064	1.100	1.137	1.177	1.220	1.315	1.426	–	15.	Gerlach.
$2NaOH+As_2O_5$ $+24H_2O$ . .	1.020	1.042	1.066	1.089	1.114	1.140	1.194	–	–	14.	Schiff.
	5	10	15	20	30	40	60	80	100		
SO_3	1.040	1.084	1.132	1.179	1.277	1.389	1.564	1.840	–	15.	Brineau.
SO_2	1.013	1.028	1.045	1.063	–	–	–	–	–	4.	Schiff.
N_2O_5	1.033	1.069	1.104	1.141	1.217	1.294	1.422	1.506	–	15.	Kolb.
$C_4H_6O_6$	1.021	1.047	1.070	1.096	1.150	1.207	–	–	–	15.	Gerlach.
$C_6H_8O_7$	1.018	1.038	1.058	1.079	1.123	1.170	1.273	–	–	15.	"
Cane sugar . . .	1.019	1.039	1.060	1.082	1.129	1.178	1.289	–	–	17.5	"
HCl	1.025	1.050	1.075	1.101	1.151	1.200	–	–	–	15.	Kolb.
HBr	1.035	1.073	1.114	1.158	1.257	1.376	–	–	–	14.	Topsöe.
HI	1.037	1.077	1.118	1.165	1.271	1.400	–	–	–	13.	"
H_2SO_4	1.032	1.069	1.106	1.145	1.223	1.307	1.501	1.732	1.838	15.	Kolb.
H_2SiFl_6	1.040	1.082	1.127	1.174	1.273	–	–	–	–	17.5	Stolba.
P_2O_5	1.035	1.077	1.119	1.167	1.271	1.385	1.676	–	–	17.5	Hager.
$P_2O_5+3H_2O$ . .	1.027	1.057	1.086	1.119	1.188	1.264	1.438	–	–	15.	Schiff.
HNO	1.028	1.056	1.088	1.119	1.184	1.250	1.373	1.459	1.528	15.	Kolb.
$C_2H_4O_2$	1.007	1.014	1.021	1.028	1.041	1.052	1.068	1.075	1.055	15.	Oudemans.

DENSITY OF WATER AT DIFFERENT TEMPERATURES BETWEEN 0° AND 36°C.

The temperatures are for the hydrogen thermometer.

Temp. C.	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
0	0.999 868	874	881	887	893	899	905	911	916	922
1	927	932	936	941	945	950	954	957	961	965
2	968	971	974	977	980	982	985	987	989	991
3	992	994	995	996	997	998	999	999	000	000
4	1.000 000	000	000	999*	999*	998*	997*	996*	995*	993*
5	0.999 992	990	988	986	984	982	979	977	974	971
6	968	965	962	958	954	951	947	943	938	934
7	929	925	920	915	910	904	899	893	888	882
8	876	870	864	857	851	844	837	830	823	816
9	808	801	793	785	778	769	761	753	744	736
10	727	718	709	700	691	681	672	662	652	642
11	632	622	612	601	591	580	569	558	547	536
12	525	513	502	490	478	466	454	442	429	417
13	404	391	379	366	353	339	326	312	299	285
14	271	257	243	229	215	200	186	171	156	141
15	126	111	096	081	065	050	034	018	002	986*
16	0.998 970	953	937	920	904	887	870	853	836	819
17	801	784	766	749	731	713	695	677	659	640
18	622	603	585	566	547	528	509	490	471	451
19	432	412	392	372	352	332	312	292	271	251
20	230	210	189	168	147	126	105	083	062	040
21	019	997*	975*	953*	931*	909*	887*	864*	842*	819*
22	0.997 797	774	751	728	705	682	659	635	612	588
23	565	541	517	493	469	445	421	396	372	347
24	323	298	273	248	223	198	173	147	122	096
25	071	045	019	994*	968*	941*	915*	889*	863*	836*
26	0.996 810	783	756	730	703	676	648	621	594	567
27	539	512	484	456	428	400	372	344	316	288
28	259	231	202	174	145	116	087	058	029	000
29	0.995 971	941	912	882	853	823	793	763	733	703
30	673	643	613	582	552	521	491	460	429	398
31	367	336	305	273	242	211	179	148	116	084
32	052	020	988*	956*	924*	892*	859*	827*	794*	762*
33	0.994 729	696	663	630	597	564	531	498	464	431
34	398	364	330	296	263	229	195	161	126	092
35	058	023	989	954	920	885	850	815	780	745

If we put D'_t for the density of water containing air and D_t for the density of water free from air, we get the following, due to Marek:

t=	0	1	2	3	4	5	6	7	8	9	10
$10^7(D_t-D'_t)$=	25	27	29	31	32	33	33	34	34	33	32

t=	11	12	13	14	15	16	17	18	19	20—32
$10^7(D_t-D'_t)$=	31	29	27	25	22	19	16	12	8	4 negligible

From the observations of Thiesen, Scheel, and Diesselhorst, Wiss. Abh. Phys.-Techn. Reichs. 3, 68; 1900.

VOLUME IN CUBIC CENTIMETRES AT VARIOUS TEMPERATURES OF A CUBIC CENTIMETRE OF WATER AT THE TEMPERATURE OF MAXIMUM DENSITY.

The water in this case is supposed to be free from air. The temperatures are by the hydrogen thermometer.

Temp. C.	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
0	1.000 132	126	119	113	107	101	095	089	084	079
1	073	069	064	059	055	051	047	043	039	035
2	032	029	026	023	020	018	016	013	011	009
3	008	006	005	004	003	002	001	001	000	000
4	000	000	000	001	001	002	003	004	005	007
5	008	010	012	014	016	018	021	023	026	029
6	032	035	039	042	046	050	054	058	062	066
7	071	075	080	085	090	096	101	107	112	118
8	124	130	137	143	149	156	163	170	177	184
9	192	199	207	215	223	231	239	247	256	264
10	273	282	291	300	309	319	328	338	348	358
11	368	378	388	399	409	420	431	442	453	464
12	476	487	499	511	522	534	547	559	571	584
13	596	609	622	635	648	661	675	688	702	715
14	729	743	757	772	786	800	815	830	844	859
15	874	890	905	920	936	951	967	983	999	015*
16	1.001 031	048	064	081	098	114	131	148	165	183
17	200	218	235	253	271	289	307	325	343	361
18	380	399	417	436	455	474	493	513	532	551
19	571	591	610	630	650	671	691	711	732	752
20	773	794	815	836	857	878	899	921	942	964
21	985	007*	029*	051*	073*	096*	118*	140*	163*	186*
22	1.002 208	231	254	277	300	324	347	370	394	418
23	441	465	489	513	538	562	586	611	635	660
24	685	710	735	760	785	810	835	861	886	912
25	938	964	990	016*	042*	068*	094*	121*	147*	174*
26	1.003 201	227	254	281	308	336	363	390	418	445
27	473	501	529	556	585	613	641	669	698	726
28	755	783	812	841	870	899	928	957	987	016*
29	1.004 046	075	105	135	165	194	225	255	285	315
30	346	376	407	437	468	499	530	561	592	623
31	655	686	717	749	781	812	844	876	908	940
32	972	005*	037*	070*	102*	135*	167*	200*	233*	266*
33	1.005 299	332	365	399	432	465	499	533	566	600
34	634	668	702	736	771	805	839	874	908	943
35	978	013*	047*	082*	118*	153*	188*	223*	259*	294*

From the observations of Thiesen, Scheel, and Diesselhorst, Wiss. Abh. Phys.-Techn. Reichs. 3, 68; 1900.

DENSITY AND VOLUME OF WATER.

The mass of one cubic centimetre at 4° C. is taken as unity.

Temp. C.	Density.	Volume.	Temp. C.	Density.	Volume.
−10°	0.9815	1.00186	+35°	0.99406	1.00598
−9	843	157	36	371	633
−8	869	131	37	336	669
−7	892	108	38	299	706
−6	912	088	39	262	743
−5	0.99930	1.00070	40	0.99224	1.00782
−4	945	055	41	186	821
−3	958	042	42	147	861
−2	970	031	43	107	901
−1	979	021	44	066	943
+0	0.99987	1.00013	45	0.99025	1.00985
1	993	007	46	0.98982	1.01028
2	997	003	47	940	072
3	999	001	48	896	116
4	1.00000	1.00000	49	852	162
5	0.99999	1.00001	50	0.98807	1.01207
6	997	003	51	762	254
7	993	007	52	715	301
8	988	012	53	669	349
9	981	019	54	621	398
10	0.99973	1.00027	55	0.98573	1.01448
11	963	037	60	324	705
12	952	048	65	059	979
13	940	060	70	0.97781	1.02270
14	927	073	75	489	576
15	0.99913	1.00087	80	0.97183	1.02899
16	897	103	85	0.96865	1.03237
17	880	120	90	534	590
18	862	138	95	192	959
19	843	157	100	0.95838	1.04343
20	0.99823	1.00177	110	0.9510	1.0515
21	802	198	120	.9434	1.0601
22	780	221	130	.9352	1.0693
23	756	244	140	.9264	1.0794
24	732	268	150	.9173	1.0902
25	0.99707	1.00294	160	0.9075	1.1019
26	681	320	170	.8973	1.1145
27	654	347	180	.8866	1.1279
28	626	375	190	.8750	1.1429
29	597	405	200	.8628	1.1590
30	0.99567	1.00435	210	0.850	1.177
31	537	466	220	.837	1.195
32	505	497	230	.823	1.215
33	473	530	240	.809	1.236
34	440	563	250	.794	1.259

* From −10° to 0° the values are due to means from Pierre, Weidner, and Rosetti; from 0° to 35°, to Thiesen, Scheel, and Diesselhorst; 31° to 100°, to Thiesen; 110° to 250°, to means from the works of Ramsey, Young, Waterston, and Hirn.

DENSITY OF MERCURY.

Density or mass in grammes per cubic centimetre, and the volume in cubic centimetres of one gramme of mercury. The density at 0° is taken as 13.59545,* and the volume at temperature t is $V_t = V_0(1 + .00018792t + 175\times10^{-12}t^2 + 35116\times10^{-16}t^3)$.†

Temp. C.	Mass in grammes per cu. cm.	Volume of 1 gramme in cu. cms.	Temp. C.	Mass in grammes per cu. cm.	Volume of 1 gramme in cu. cms.
−10°	13.6202	0.0734205	**30°**	13.5217	0.0739552
−9	6177	4338	31	5193	9686
−8	6152	4472	32	5168	9820
−7	6128	4606	33	5144	9953
−6	6103	4739	34	5119	40087
−5	13.6078	0.0734873	**35**	13.5095	0.0740221
−4	6053	5006	36	5070	0354
−3	6029	5140	37	5046	0488
−2	6004	5273	38	5021	0622
−1	5979	5407	39	4997	0756
0	13.5955	0.0735540	**40**	13.4973	0.0740891
1	5930	5674	50	4729	2229
2	5906	5808	60	4486	3569
3	5881	5941	70	4244	4910
4	5856	6075	80	4003	6252
5	13.5832	0.0736209	**90**	13.3762	0.0747594
6	5807	6342	100	3522	8939
7	5782	6476	110	3283	50285
8	5758	6610	120	3044	1633
9	5733	6744	130	2805	2982
10	13.5708	0.0736877	**140**	13.2567	0.0754334
11	5684	7011	150	2330	5688
12	5659	7145	160	2093	7044
13	5634	7278	170	1856	8402
14	5610	7412	180	1620	9764
15	13.5585	0.0737546	**190**	13.1384	0.0761128
16	5561	7680	200	1148	2495
17	5536	7813	210	0913	3865
18	5512	7947	220	0678	5239
19	5487	8081	230	0443	6616
20	13.5462	0.0738215	**240**	13.0209	0.0767996
21	5438	8348	250	12.9975	9381
22	5413	8482	260	9741	70769
23	5389	8616	270	9507	2161
24	5364	8750	280	9273	3558
25	13.5340	0.0738883	**290**	12.9039	0.0774958
26	5315	9017	300	8806	6364
27	5291	9151	310	8572	7774
28	5266	9285	320	8339	9189
29	5242	9419	330	8105	80609
30	13.5217	0.0739552	**340**	12.7872	0.0782033
			350	7638	3464
			360	7405	4900

* Thiesen und Scheel, Thätigkeitsbericht der Phys. Reichsanstalt, 1897–1898.
† Broch, *l. c.*

TABLE 77.

SPECIFIC GRAVITY OF AQUEOUS ETHYL ALCOHOL.

(a) The numbers here tabulated are the specific gravities at 60° F., in terms of water at the same temperature, of water containing the percentages by weight of alcohol of specific gravity .7938, with reference to the same temperatures.*

Percentage of alcohol by weight.	0	1	2	3	4	5	6	7	8	9
	Specific gravity at 15°.56 C. in terms of water at the same temperature.									
0	1.0000	.9981	.9965	.9947	.9930	.9914	.9898	.9884	.9869	.9855
10	.9841	.9828	.9815	.9802	.9789	.9778	.9766	.9753	.9741	.9728
20	.9716	.9703	.9691	.9678	.9665	.9652	.9638	.9623	.9609	.9593
30	.9578	.9560	.9544	.9528	.9511	.9490	.9470	.9452	.9434	.9416
40	.9396	.9376	.9356	.9335	.9314	.9292	.9270	.9249	.9228	.9206
50	0.9184	.9160	.9135	.9113	.9090	.9069	.9047	.9025	.9001	.8979
60	.8956	.8932	.8908	.8886	.8863	.8840	.8816	.8793	.8769	.8745
70	.8721	.8696	.8672	.8649	.8625	.8603	.8581	.8557	.8533	.8508
80	.8483	.8459	.8434	.8408	.8382	.8357	.8331	.8305	.8279	.8254
90	.8228	.8199	.8172	.8145	.8118	.8089	.8061	.8031	.8001	.7969

(b) The following are the values adopted by the "Kaiserlichen Normal-Aichungs Kommission." They are based on Mendelejeff's formula,† and are for alcohol of specific gravity .79425, at 15° C., in terms of water at 15° C.; temperatures measured by the hydrogen thermometer.

Percentage of alcohol by weight.	0	1	2	3	4	5	6	7	8	9
	Specific gravity at 15° C. in terms of water at the same temperature.									
0	1.00000	.99812	.99630	.99454	.99284	.99120	.98963	.98812	.98667	.98528
10	.98393	.98262	.98135	.98010	.97888	.97768	.97648	.97528	.97408	.97287
20	.97164	.97040	.96913	.96783	.96650	.96513	.96373	.96228	.96080	.95927
30	.95770	.95608	.95443	.95273	.95099	.94920	.94738	.94552	.94363	.94169
40	.93973	.93773	.93570	.93365	.93157	.92947	.92734	.92519	.92303	.92085
50	0.91865	.91644	.91421	.91197	.90972	.90746	.90519	.90292	.90063	.89834
60	89604	.89373	.89141	.88909	.88676	.88443	.88208	.87974	.87738	.87502
70	87265	.87028	.86789	.86550	.86310	.86070	.85828	.85586	.85342	.85098
80	84852	.84606	.84358	.84108	.83857	.83604	.83349	.83091	.82832	.82569
90	82304	.82036	.81763	.81488	.81207	.80923	.80634	.80339	.80040	.79735

(c) The following values have the same authority as the last; the percentage of alcohol being given by volume instead of by weight, and the temperature 15°.56 C. on the mercury in Thuringian glass thermometer; the specific gravity of the absolute alcohol being .79391.

Percentage of alcohol by volume.	0	1	2	3	4	5	6	7	8	9
	Specific gravity at 15°.56 C. in terms of water at same temperature.									
0	1.00000	.99847	.99699	.99555	.99415	.99279	.99147	.99019	.98895	.98774
10	.98657	.98543	.98432	.98324	.98218	.98114	.98011	.97909	.97808	.97708
20	.97608	.97507	.97406	.97304	.97201	.97097	.96991	.96883	.96772	.96658
30	.96541	.96421	.96298	.96172	.96043	.95910	.95773	.95632	.95487	.95338
40	.95185	.95029	.94868	.94704	.94536	.94364	.94188	.94008	.93824	.93636
50	0.93445	.93250	.93052	.92850	.92646	.92439	.92229	.92015	.91799	.91580
60	.91358	.91134	.90907	.90678	.90447	.90214	.89978	.89740	.89499	.89256
70	.89010	.88762	.88511	.88257	.88000	.87740	.87477	.87211	.86943	.86670
80	.86395	.86116	.85833	.85547	.85256	.84961	.84660	.84355	.84044	.83726
90	.83400	.83065	.82721	.82365	.81997	.81616	.81217	.80800	.80359	.79891

* Fownes, "Phil. Trans. Roy. Soc." 1847.
† "Pogg. Ann." vol. 138, 1869.

DENSITY OF AQUEOUS METHYL ALCOHOL.*

Densities of aqueous methyl alcohol at 0° and 15.56 C., water at 4° C. being taken as 100000. The numbers in the columns a and b are the coefficients in the equation $\rho_t = \rho_0 - at - bt^2$ where ρ_t is the density at temperature t. This equation may be taken to hold between 0° and 20° C.

Percentage of CH_4O.	Density at 0° C.	Density at 15°.56 C.	a	b	Percentage of CH_4O.	Density at 0° C.	Density at 15°.56 C.	a
0	99987	99907	−6.0	0.705	50	92873	91855	65.41
1	99806	99729	−5.4	.694	51	92691	91661	66.19
2	99631	99554	−4.8	.681	52	92507	91465	66.95
3	99462	99382	−3.9	.670	53	92320	91267	67.68
4	99299	99214	−3.0	.659	54	92130	91066	68.39
5	99142	99048	−2.2	0.648	55	91938	90863	69.07
6	98990	98893	−1.2	.634	56	91742	90657	69.72
7	98843	98726	−0.2	.621	57	91544	90450	70.35
8	98701	98569	+0.9	.609	58	91343	90239	70.96
9	98563	98414	2.1	.596	59	91139	90026	71.54
10	98429	98262	3.3	0.581	60	90917	89798	71.96
11	98299	98111	4.8	.569	61	90706	89580	72.37
12	98171	97962	6.2	.552	62	90492	89358	72.91
13	98048	97814	7.8	.536	63	90276	89133	73.45
14	97926	97668	9.5	.519	64	90056	88905	73.98
15	97806	97523	11.0	0.500	65	89835	88676	74.51
16	97689	97379	12.5	.480	66	89611	88443	75.05
17	97573	97235	14.5	.461	67	89384	88208	75.57
18	97459	97093	16.2	.440	68	89154	87970	76.10
19	97346	96950	18.3	.420	69	88922	87714	76.62
20	97233	96808	20.0	0.398	70	88687	87487	77.14
21	97120	96666	22.2	.373	71	88470	87262	77.66
22	97007	96524	24.3	.350	72	88237	87021	78.18
23	96894	96381	26.4	.321	73	88003	86779	78.69
24	96780	96238	29.0	.291	74	87767	86535	79.20
25	96665	96093	31.3	0.261	75	87530	86290	79.71
26	96549	95949	33.8	.230	76	87290	86042	80.22
27	96430	95802	36.0	.191	77	87049	85793	80.72
28	96310	95655	38.8	.151	78	86806	85542	81.23
29	96187	95506	41.1	.106	79	86561	85290	81.73
Equation $\rho_t = \rho_0 - at$					80	86314	85035	82.22
30	96057	95367	44.36		81	86066	84779	82.72
31	95921	95211	45.66		82	85816	84521	83.21
32	95783	95053	46.93		83	85564	84262	83.70
33	95643	94894	48.17		84	85310	84001	84.19
34	95500	94732	49.39		85	85055	83738	84.67
35	95354	94567	50.58		86	84798	83473	85.16
36	95204	94399	51.75		87	84539	83207	85.64
37	95051	94228	52.89		88	84278	82938	86.12
38	94895	94055	54.01		89	84015	82668	86.59
39	94734	93877	55.10		90	83751	82396	87.07
40	94571	93697	56.16		91	83485	82123	87.54
41	94400	93510	57.20		92	83218	81849	88.01
42	94239	93335	58.22		93	82948	81572	88.48
43	94076	93155	59.20		94	82677	81293	88.94
44	93911	92975	60.17		95	82404	81013	89.40
45	93744	92793	61.10		96	82129	80731	89.86
46	93575	92610	62.01		97	81853	80448	90.32
47	93403	92424	62.90		98	81576	80164	90.78
48	93229	92237	63.76		99	81295	79872	91.23
49	93052	92047	64.60		100	81015	79589	91.68

Term bt^2 negligible.

* Quoted from the results of *Dittmar & Fawsitt*, "Trans. Roy. Soc. Edin." vol. 33.

VARIATION OF THE DENSITY OF ALCOHOL WITH TEMPERATURE.

(a) The density of alcohol at $t°$ in terms of water at 4° is given* by the following equation:

$$d_t = 0.80025 - 0.000834\alpha t - 0.0000029t^2.$$

From this formula the following table has been calculated.

Temp. C.	Density or Mass in grammes per cubic centimetre.									
	0	1	2	3	4	5	6	7	8	9
0	.80625	.80541	.80457	.80374	.80290	.80207	.80123	.80039	.79956	.79872
10	.79788	.79704	.79620	.79535	.79451	.79367	.79283	.79198	.79114	.79029
20	.78945	.78860	.78775	.78691	.78606	.78522	.78437	.78352	.78267	.78182
30	.78097	.78012	.77927	.77841	.77756	.77671	.77585	.77500	.77414	.77329

(b) Variations with temperature of the density of water containing different percentages of alcohol. Water at 4° C. is taken as unity.†

Percentage of alcohol by weight.	Density at temp. C.				Percentage of alcohol by weight.	Density at temp. C.			
	0°	10°	20°	30°		0°	10°	20°	30°
0	0.99988	0.99975	0.99831	0.99579	50	0.92940	0.92182	0.91400	0.90577
5	.99135	.99113	.98945	.98680	55	.91848	.91074	.90275	.89456
10	.98493	.98409	.98195	.97892	60	.90742	.89944	.89129	.88304
15	.97995	.97816	.97527	.97142	65	.89595	.88790	.97961	.87125
20	.97566	.97263	.96877	.96413	70	.88420	.87613	.86781	.85925
25	0.97115	0.96672	0.96185	0.95628	75	0.87245	0.86427	0.85580	0.84719
30	.96540	.95998	.95403	.94751	80	.86035	.85215	.84366	.83483
35	.95784	.95174	.94514	.93813	85	.84789	.83967	.83115	.82232
40	.94939	.94255	.93511	.92787	90	.83482	.82665	.81801	.80918
45	.93977	.93254	.92493	.91710	95	.82119	.81291	.80433	.79553
50	0.92940	0.92182	0.91400	0.90577	100	0.80625	0.79788	0.78945	0.78096

* Mendelejeff, "Pogg. Ann." vol. 138.

† Quoted from Landolt and Börnstein, "Phys. Chem. Tab." p. 359.

VELOCITY OF SOUND IN SOLIDS.

The numbers given in this table refer to the velocity of sound along a bar of the substance, and hence depend on the Young's Modulus of elasticity of the material. The elastic constants of most of the materials given in this table vary through a somewhat wide range, and hence the numbers can only be taken as rough approximations to the velocity which may be obtained in any particular case. When temperatures are not marked, between 10° and 20° is to be understood.

Substance.	Temp. C.	Velocity in metres per second.	Velocity in feet per second.	Authority.
Metals: Aluminum	0 –	5104	16740	Masson.
Brass	–	3500	11480	Various.
Cadmium	–	2307	7570	Masson.
Cobalt	–	4724	15500	"
Copper	20	3560	11670	Wertheim.
"	100	3290	10800	"
"	200	2950	9690	"
Gold (soft)	20	1743	5717	"
" (hard)	–	2100	6890	Various.
Iron and soft steel	–	5000	16410	"
Iron	20	5130	16820	Wertheim.
"	100	5300	17390	"
"	200	4720	15480	"
" cast steel	20	4990	16360	"
" " "	200	4790	15710	"
Lead	20	1227	4026	"
Magnesium	–	4602	15100	Melde.
Nickel	–	4973	16320	Masson.
Palladium	–	3150	10340	Various.
Platinum	20	2690	8815	Wertheim.
"	100	2570	8437	"
"	200	2460	8079	"
Silver	20	2610	8553	"
"	100	2640	8658	"
Tin	–	2500	8200	Various.
Zinc	–	3700	12140	"
Various: Brick	–	3652	11980	Chladni.
Clay rock	–	3480	11420	Gray & Milne.
Cork	–	500	1640	Stefan.
Granite	–	3950	12960	Gray & Milne.
Marble	–	3810	12500	"
Paraffin	15	1304	4280	Warburg.
Slate	–	4510	14800	Gray & Milne.
Tallow	16	390	1280	Warburg.
Tuff	–	2850	9350	Gray & Milne.
Glass from	–	5000	16410	Various.
Glass to	–	6000	19690	"
Ivory	–	3013	9886	Ciccone & Campanile.
Vulcanized rubber	0	54	177	Exner.
(black)	50	31	102	"
" " (red)	0	69	226	"
" " "	70	34	111	"
Wax	17	880	2890	Stefan.
"	28	441	1450	"
Woods: Ash, along the fibre	–	4670	15310	Wertheim.
" across the rings	–	1390	4570	"
" along the rings	–	1260	4140	"
Beech, along the fibre	–	3340	10960	"
" across the rings	–	1840	6030	"
" along the rings	–	1415	4640	"
Elm, along the fibre	–	4120	13516	"
" across the rings	–	1420	4665	"
" along the rings	–	1013	3324	"
Fir, along the fibre	–	4640	15220	"
Maple "	–	4110	13470	"
Oak "	–	3850	12620	"
Pine "	–	3320	10900	"
Poplar "	–	4280	14050	"
Sycamore "	–	4460	14640	"

TABLE 81.

VELOCITY OF SOUND IN LIQUIDS AND GASES.

Substance.	Temp. C.	Velocity in metres per second.	Velocity in feet per second.	Authority.
	°			
Liquids: Alcohol, 95%	12.5	1241.	4072.	Dorsing, 1908.
" "	20.5	1213.	3980.	"
Ammonia, conc.	16.	1663.	5456.	"
Benzine	17.	1166.	3826.	"
Carbon bisulphide	15.	1161.	3809.	"
Chloroform	15.	983.	3225.	"
Ether	15.	1032.	3386.	"
NaCl, 10% sol.	15.	1470.	4823.	"
" 15% "	15.	1530.	5020.	"
" 20% "	15.	1650.	5414.	"
Turpentine oil	15.	1326.	4351.	"
Water, air-free	13.	1441.	4728.	"
" " "	19.	1461.	4794.	"
" " "	31.	1505.	4938.	"
" Lake Geneva	9.	1435.	4708.	Colladon-Sturm.
" Seine river	15.	1437.	4714.	Wertheim.
" " "	30.	1528.	5013.	"
" " "	60.	1724.	5657.	"
Gases: Air, dry, CO_2-free	0.	331.78	1088.5	Rowland.
" "	0.	331.36	1087.1	Violle, 1900.
" " CO_2-free	0.	331.92	1089.0	Thiesen, 1908.
" 1 atmosphere	0.	331.7	1088.	Mean.
" 25 "	0.	332.0	1089.	" (Witkowski).
" 50 "	0.	334.7	1098.	" "
" 100 "	0.	350.6	1150.	" "
"	20.	344.	1129.	
"	100.	386.	1266.	Stevens.
"	500.	553.	1814.	"
"	1000.	700.	2297.	"
Ammonia	0.	415.	1361.	Masson.
Carbon monoxide	0.	337.1	1106.	Wullner.
" "	0.	337.4	1107.	Dulong.
" dioxide	0.	258.0	846.	Brockendahl, 1906.
" disulphide	0.	189.	606.	Masson.
Chlorine	0.	206.4	677.	Martini.
"	0.	205.3	674.	Strecker.
Ethylene	0.	314.	1030.	Dulong.
Hydrogen	0.	1269.5	4165.	"
"	0.	1286.4	4221.	Zoch.
Illuminating gas	0.	490.4	1609.	"
Methane	0.	432.	1417.	Masson.
Nitric oxide	0.	325.	1066.	"
Nitrous oxide	0.	261.8	859.	Dulong.
Oxygen	0.	317.2	1041.	"
Vapors: Alcohol	0.	230.6	756.	Masson.
Ether	0.	179.2	588.	"
Water	0.	401.	1315.	"
"	100.	404.8	1328.	Treitz, 1903.
"	130.	424.4	1392.	"

MUSICAL SCALES.

The pitch relations between two notes may be expressed precisely (1) by the ratio of their vibration frequencies; (2) by the number of equally-tempered semitones between them (E. S.); also, less conveniently, (3) by the common logarithm of the ratio in (1); (4) by the lengths of the two portions of the tense string which will furnish the notes; and (5) in terms of the octave as unity. The ratio in (4) is the reciprocal of that in (1); the number for (5) is 1/12 of that for (2); the number for (2) is nearly 40 times that for (3).

Table 82 gives data for the middle octave, including vibration frequencies for three standards of pitch; $a = 435$ double vibrations per second, is the international standard and was adopted by the American Piano Manufacturers' Association. The "just-diatonic scale" of C-major is usually deduced, following Chladni, from the ratios of the three perfect major triads reduced to one octave, thus:

4	:	5	:	6			4	:	5	:	6			
F		A		C			E		G		B		D	
16		20		24			30		36		45		54	
				24	27	30	32	36	40	45	48			

Other equivalent ratios and their values in E. S. are given in Table 83. By transferring D to the left and using the ratio 10 : 12 : 15 the scale of A-minor is obtained, which agrees with that of C-major except that $D = 26\ 2/3$. Nearly the same ratios are obtained from a series of harmonics beginning with the eighth; also by taking 12 successive perfect or Pythagorean fifths or fourths and reducing to one octave. Such calculations are most easily made by adding and subtracting intervals expressed in E. S. The notes needed to furnish a just major scale in other keys may be found by successive transpositions by fifths or fourths as shown in Table 83. Disregarding the usually negligible difference of 0.02 E. S., the table gives the 24 notes to the octave required in the simplest enharmonic organ; the notes fall into pairs that differ by a comma, 0.22 E. S. The line "mean tone" is based on Dom Bedos' rule for tuning the organ (1746). The tables have been checked by the data in Ellis' Helmholtz's "Sensations of Tone."

TABLE 82.

Note.	Interval.		Ratios.		Logarithms.		Number of Vibrations per second.				Beats for 0.1 E. S.
	Tempered.	Just.	Tempered.	Just.	Tempered.	Just.	Just.	Just.	Just.	Tempered.	
	E. S.	E. S.									
c′	0	0.	1.00	1.00000	0.0000	0.00000	*256*	*264*	258.7	258.7	1.50
	1			1.05926		.02509				274.0	
d′	2	2.04	1.125	1.12246	.05115	.05017	288	297	291.0	290.3	1.68
	3			1.18921		.07526				307.6	
e′	4	3.86	1.25	1.25992	.09691	.10034	320	330	323.4	325.9	1.89
f′	5	4.98	1.33	1.33484	.12494	.12543	341.3	352	344.9	345.3	2.00
	6			1.41421		.15051				365.8	
g′	7	7.02	1.50	1.49831	.17609	.17560	384	396	388	387.5	2.25
	8			1.58740		.20069				410.6	
a′	9	8.84	1.67	1.68179	.22185	.22577	426.7	*440*	431.1	*435.0*	2.52
	10			1.78180		.25086				460.9	
b′	11	10.88	1.875	1.88775	.27300	.27594	480	495	485.0	488.3	2.83
c″	12	12.00	2.00	2.00000	.30103	.30103	512	528	517.3	517.3	3.00

TABLE 83.

Key of	C		D		E	F		G		A		B	C
7 ♯s C♯		1.14		3.18		5.00	6.12		8.16		9.98		12.02
		0.92		2.96		4.78	5.90		7.94		9.76		11.80
6 " F♯		1.14		2.96		5.00	6.12		8.16		9.98	11.10	
		0.92		2.74		4.78	5.90		7.94		9.76	10.88	
5 " B		1.14		2.96	4.08		6.12		7.94		9.98	11.10	
		0.92		2.74	3.86		5.90		7.72		9.76	10.88	
4 " E		0.92		2.96	4.08		6.12		7.94	9.06		11.10	
		0.70		2.74	3.86		5.90		7.72	8.84		10.88	
3 " A		0.92	2.04		4.08		5.90		7.94	9.06		11.10	
		0.70	1.82		3.86		5.68		7.72	8.84		10.88	
2 " D		0.92	2.04		4.08		5.90	7.02		9.06		10.88	
1 ♯ G	0.00		2.04		3.86		5.90	7.02		9.06		10.88	12.00
C	0.00		2.04		3.86	4.98		7.02		8.84		10.88	12.00
1 ♭ F	0.00		1.82		3.86	4.98		7.02		8.84	9.96		12.00
2 ♭s B♭	0.00		1.82	2.94		4.98		6.80		8.84	9.96		12.00
3 " E♭	−.22		1.82	2.94		4.98		6.80	7.92		9.96		11.78
4 " A♭	−.22	0.90		2.94		4.76		6.80	7.92		9.96		11.78
5 " D♭	−.22	0.90		2.94		4.76	5.88		7.92		9.74		11.78
6 " G♭		0.90		2.72		4.76	5.88		7.92		9.74	10.86	
7 " C♭		0.90		2.72	3.84		5.88		7.70		9.74	10.86	

Harmonic Series	8	(1.71)	9	(19)	10	(21)	11	12	(25)	13	14	15	16
	0.0	(1.05)	2.04	(2.98)	3.86	(4.70)	5.51	7.02	(7.73)	8.41	9.69	10.88	12.00
Cycle of fifths	0.0	1.14	2.04	3.18	4.08	5.22	6.12	7.02	8.16	9.06	10.20	11.10	12.24
Cycle of fourths	0.0	0.90	1.80	2.94	3.84	4.98	5.88	6.78	7.92	8.82	9.96	10.86	11.76
Mean tone	0.0	0.76	1.93	3.11	3.86	5.03	5.79	6.97	7.72	8.90	10.07	10.83	12.00
Equal 7 step	0.0		1.71	3 43		5.14		6.86		8.57	10.29		12.00

TABLE 84. ACCELERATION OF GRAVITY.

For Sea Level and Different Latitudes.

This table has been calculated from the formula $g_\phi = g_{45}\,[1 - .002662 \cos 2\phi]$,* where ϕ is the latitude.

Latitude ϕ.	g in cms. per sec. per sec.	Log.	g in inches per sec. per sec.	Log.	g in feet per sec. per sec.	Log.
0°	977.989	2.990334	385.034	2.585498	32.0862	1.506318
5	8.029	0352	.050	5517	.0875	6336
10	.147	0404	.096	5570	.0916	6388
15	.339	0490	.173	5655	.0977	6474
20	.600	0605	.275	5771	.1062	6590
25	978.922	2.990748	385.402	2.585914	32.1168	1.506732
30	9.295	0913	.548	6079	.1290	6898
31	.374	0949	.580	6114	.1316	6933
32	.456	0985	.612	6150	.1343	6969
33	.538	1021	.644	6187	.1370	7005
34	979.622	2.991059	385.677	2.586224	32.1398	1.507043
35	.707	1096	.711	6262	.1425	7080
36	.793	1135	.745	6300	.1454	7119
37	.880	1173	.779	6339	.1490	7167
38	.968	1212	.813	6377	.1511	7196
39	980.057	2.991251	385.849	2.586417	32.1540	1.507236
40	.147	1291	.884	6457	.1570	7275
41	.237	1331	.919	6496	.1607	7325
42	.327	1372	.955	6537	.1630	7356
43	.418	1411	.990	6577	.1659	7395
44	980.509	2.991452	386.026	2.586617	32.1688	1.507436
45	.600	1492	.062	6657	.1719	7476
46	.691	1532	.098	6698	.1748	7516
47	.782	1573	.134	6738	.1778	7557
48	.873	1613	.170	6778	.1808	7597
49	980.963	2.991653	386.205	2.586818	32.1838	1.507637
50	1.053	1693	.241	6858	.1867	7677
51	.143	1732	.276	6898	.1896	7716
52	.231	1772	.311	6937	.1924	7756
53	.318	1810	.345	6975	.1954	7794
54	981.407	2.991849	386.380	2.587014	32.1983	1.507833
55	.493	1887	.414	7053	.2011	7871
56	.578	1925	.447	7090	.2039	7909
57	.662	1962	.480	7127	.2067	7946
58	.744	1998	.513	7164	.2094	7983
59	981.825	2.992034	386.545	2.587200	32.2121	1.508018
60	.905	2070	.576	7235	.2147	8054
65	2.278	2234	.723	7400	.2276	8229
70	.600	2377	.849	7542	.2375	8361
75	.861	2492	.952	7657	.2460	8476
80	983.053	2.992577	387.028	2.587742	32.2523	1.508561
85	.171	2629	.074	7794	.2562	8613
90	.210	2646	.090	7812	.2575	8631

* The constant .002662 is based on Harkness' data (Solar Parallax and Related Constants, Washington, 1891). The acceleration of gravity for any latitude ϕ and elevation above sea level h is very nearly expressed by the equation

$$g_\phi = g_{45}\,(1 - .002662 \cos 2\phi)\left[1 - \frac{2h}{R}\left(1 - \frac{3\delta}{4\Delta}\right)\right],$$

where R is the earth's radius, δ the density of the surface strata, and Δ the mean density of the earth. When $\delta = 0$ we get the formula for elevation in air. For ordinary elevations on land $\frac{\delta}{\Delta}$ is nearly $\frac{1}{2}$, which gives for the correction at latitude 45° for elevated portions of the earth's surface

$$g_{45}\frac{5h}{4R} = 980.6 \times \frac{5h}{4R} = 1225.75\frac{h}{R} \text{ cm. per sec. per sec.}$$

$$= 386.062 \times \frac{5h}{4R} = 482.562\frac{h}{R} \text{ in. per sec. per sec.}$$

$$= 32.1719 \times \frac{5h}{4R} = 40.2149\frac{h}{R} \text{ feet per sec. per sec.}$$

This gives per 100 feet elevation a correction of

.00588 cm. per sec. per sec.
.00232 in. per sec. per sec.
.000193 feet per sec. per sec.
} diminution.

TABLE 85.
GRAVITY.

In this table the results of a number of the more recent gravity determinations are brought together. They serve to show the degree of accuracy which may be assumed for the numbers in Table 112. In general, gravity is a little lower than the calculated value for stations far inland and slightly higher on the coast line.

Place.	Latitude. N. +, S. −.	Elevation in metres.	Gravity, $\frac{cm.}{sec^2}$		Reference.
			Observed.	Reduced to sea level.	
Singapore	1° 17′	14	978.08	978.08	1
Georgetown, Ascension	−7 56	5	978.25	978.25	2
Green Mountain, Ascension	−7 57	686	978.10	978.23	2
Loanda, Angola	−8 49	46	978.15	978.16	2
Caroline Islands	−10 00	2	978.37	978.37	3
Bridgetown, Barbadoes	13 04	18	978.18	978.18	2
Jamestown, St. Helena	−15 55	10	978.67	978.67	2
Longwood, "	−15 57	533	978.53	978.59	2
Pakaoao, Sandwich Islands	20 43	3001	978.28	978.85	3
Lahaina, " "	20 52	3	978.86	978.86	3
Haiki, " "	20 56	117	978.91	978.93	3
Honolulu, " "	21 18	3	978.97	978.97	3
St. Georges, Bermuda	32 23	2	979.77	979.77	2
Sidney, Australia	−33 52	43	979.68	979.69	1
Cape Town	−33 56	11	979.62	979.62	2
Tokio, Japan	35 41	6	979.95	979.95	1
Auckland, New Zealand	−36 52	43	979.68	979.69	1
Mount Hamilton, Cal. (Lick Obs.)	37 20	1282	979.66	979.91	4
" " " "	37 20	1282	979.68	979.92	5
San Francisco, Cal.	37 47	114	979.96	979.98	4
" " "	37 47	114	980.02	980.04	5
Washington, D. C.*	38 53	10	980.11	980.11	4
Denver, Colo.	39 54	1645	979.68	979.98	5
York, Pa.	39 58	122	980.12	980.14	6
Ebensburgh, Pa.	40 27	651	980.08	980.20	6
Allegheny, Pa.	40 28	348	980.09	980.15	6
Hoboken, N. J.	40 44	11	980.27	980.27	4
Salt Lake City, Utah	40 46	1288	979.82	980.05	5
Chicago, Ill.	41 49	165	980.34	980.37	5
Pampaluna, Spain	42 49	450	980.34	980.42	7
Montreal, Canada	45 31	100	980.73	980.75	5
Geneva, Switzerland	46 12	405	980.58	980.64	8
" "	46 12	405	980.60	980.66	9
Berne, "	46 57	572	980.61	980.69	9
Zurich, "	47 23	466	980.67	980.74	9
Paris, France	48 50	67	980.96	980.97	8
Kew, England	51 28	7	981.20	981.20	8
Berlin, Germany	52 30	49	981.26	981.27	8
Port Simpson, B. C.	54 34	6	981.46	981.46	4
Burroughs Bay, Alaska	55 59	0	981.51	981.51	4
Wrangell, "	56 28	7	981.60	981.60	4
Sitka, "	57 03	8	981.69	981.69	4
St. Paul's Island, "	57 07	12	981.67	981.67	4
Juneau, "	58 18	5	981.74	981.74	4
Pyramid Harbor, "	59 10	5	981.82	981.82	4
Yakutat Bay, "	59 32	4	981.83	981.83	4

1 Smith: "United States Coast and Geodetic Survey Report for 1884," App. 14.
2 Preston: "United States Coast and Geodetic Survey Report for 1890," App. 12.
3 Preston: Ibid. 1888, App. 14.
4 Mendenhall: Ibid. 1891, App. 15.
5 Defforges: "Comptes Rendus," vol. 118, p. 231.
6 Pierce: "U. S. C. and G. S. Rep. 1883," App. 19.
7 Cebrian and Los Arcos: "Comptes Rendus des Séances de la Commission Permanente de l'Association Géodesique International," 1893.
8 Pierce: "U. S. C. and G. S. Report 1876, App. 15, and 1881, App. 17."
9 Messerschmidt: Same reference as 7.

* For references 1-4, values are derived by comparative experiments with invariable pendulums, the value for Washington taken as 980.111. For the latter see Appendix 5 of the Coast and Geodetic Survey Report for 1901.

SUMMARY OF RESULTS OF THE VALUE OF GRAVITY (g) AT STATIONS IN THE UNITED STATES AND ALASKA.*

Station.	Latitude.	Longitude.	Elevation.	g observed.
	° ′ ″	° ′ ″	Metres.	cm./sec.²
Calais, Me.	45 11 11	67 16 54	38	980.630
Boston, Mass.	42 21 33	71 03 50	22	980.395
Cambridge, Mass.	42 22 48	71 07 45	14	980.397
Worcester, Mass.	42 16 29	71 48 28	170	980.323
New York, N. Y.	40 48 27	73 57 43	38	980.266
Princeton, N. J.	40 20 57	74 39 28	64	980.177
Philadelphia, Pa.	39 57 06	75 11 40	16	980.195
Ithaca, N. Y.	42 27 04	76 29 00	247	980.299
Baltimore, Md.	39 17 50	76 37 30	30	980.096
Washington, C. & G. S.	38 53 13	77 00 32	14	980.111
Washington, Smithsonian	38 53 20	77 01 32	10	980.113
Charlottesville, Va.	38 02 01	78 30 16	166	979.937
Deer Park, Md.	39 25 02	79 19 50	770	979.934
Charleston, S. C.	32 47 14	79 56 03	6	979.545
Cleveland, Ohio	41 30 22	81 36 38	210	980.240
Key West, Fla.	24 33 33	81 48 25	1	978.969
Atlanta, Ga.	33 44 58	84 23 18	324	979.523
Cincinnati, Ohio	39 08 20	84 25 20	245	980.003
Terre Haute, Ind.	39 28 42	87 23 49	151	980.071
Chicago, Ill.	41 47 25	87 36 03	182	980.277
Madison, Wis. (Univ. of Wis.)	43 04 35	89 24 00	270	980.364
New Orleans, La.	29 56 58	90 04 14	2	979.323
St. Louis, Mo.	38 38 03	90 12 13	154	980.000
Little Rock, Ark.	34 44 57	92 16 24	89	979.720
Kansas City, Mo.	39 05 50	94 35 21	278	979.989
Galveston, Tex.	29 18 12	94 47 29	3	979.271
Austin, Texas (University)	30 17 11	97 44 14	189	979.282
Austin, Texas (Capitol)	30 16 30	97 44 16	170	979.287
Ellsworth, Kan.	38 43 43	98 13 32	469	979.925
Laredo, Tex.	27 30 29	99 31 12	129	979.081
Wallace, Kan.	38 54 44	101 35 26	1005	979.754
Colorado Springs, Col.	38 50 44	104 49 02	1841	979.489
Denver, Col.	39 40 36	104 56 55	1638	979.608
Pike's Peak, Col.	38 50 20	105 02 02	4293	978.953
Gunnison, Col.	38 32 33	106 56 02	2340	979.341
Grand Junction, Col.	39 04 09	108 33 56	1398	979.632
Green River, Utah	38 59 23	110 09 56	1243	979.635
Grand Canyon, Wyo.	44 43 16	110 29 44	2386	979.898
Norris Geyser Basin, Wyo.	44 44 09	110 42 02	2276	979.949
Lower Geyser Basin, Wyo.	44 33 21	110 48 08	2200	979.931
Pleasant Valley Jct., Utah	39 50 47	111 00 46	2191	979.511
Salt Lake City, Utah	40 46 04	111 53 46	1322	979.802
Ft. Egbert, Eagle, Alaska	64 47 22	141 12 24	174	982.182

* All the values in this table depend on relative determination of gravity and an adopted value for gravity at Washington (Coast and Geodetic Survey Office) of 980.111. This adopted value was the result of the determination in 1900 of the relative value of gravity at Potsdam and at Washington. See footnote on previous page.

LENGTH OF THE SECONDS PENDULUM.

TABLE 87.—Length of Seconds Pendulum at Sea Level for Different Latitudes.*

Length in centimetres.	Log.	Length in inches.	Log.	Latitude.	Length in centimetres.	Log.	Length in inches.	Log.
99.0910	1.996034	39.0121	1.591200	**50**	99.4014	1.997393	39.1344	1.592558
.0950	6052	.0137	1217	55	.4459	7587	.1520	2753
.1079	6104	.0184	1270	60	.4876	7770	.1683	2935
.1265	6190	.0261	1356	65	.5255	7935	.1832	3100
.1529	6306	.0365	1471	70	.5581	8077	.1960	3242
99.1855	1.996448	39.0493	1.591614	**75**	99.5845	1.998192	39.2065	1.593358
.2234	6614	.0642	1779	80	.6040	8277	.2141	3442
.2651	6796	.0806	1962	85	.6160	8329	.2188	3494
.3096	6991	.0982	2157	90	.6200	8347	.2204	3512
.3555	7192	.1163	2357					

iculated from force of gravity table by the formula $l = g/\pi^2$. For each 100 feet of elevation subtract 0.000596 tres, or 0.000235 inches, or .0000196 feet.

TABLE 88.—Length of the Seconds Pendulum.*

t of mi- on.	Number of observation stations.	Range of latitude included by the stations.	Length of pendulum in metres for latitude ϕ.	Corresponding length of pendulum for lat. 45°	Reference.
99	15	From +67° 05′ to −33° 56′	$0.990631 + .005637 \sin^2\phi$	0.993450	1
16	31	" +74° 53′ " −51° 21′	$0.990743 + .005466 \sin^2\phi$	0.993976	2
21	8	" +38° 40′ " −60° 45′	$0.990880 + .005340 \sin^2\phi$	0.993550	3
25	25	" +79° 50′ " −12° 59′	$0.990977 + .005142 \sin^2\phi$	0.993548	4
27	41	" +79° 50′ " −51° 35′	$0.991026 + .005072 \sin^2\phi$	0.993562	5
29	5	" 0° 0′ " +67° 04′	$0.990555 + .005679 \sin^2\phi$	0.993395	6
30	49	" +79° 51′ " −51° 35′	$0.991017 + .005087 \sin^2\phi$	0.993560	7
33	—	" — " —	$0.990941 + .005142 \sin^2\phi$	0.993512	8
59	51	" +79° 50′ " −51° 35′	$0.990970 + .005185 \sin^2\phi$	0.993554†	9
76	73	" +79° 50′ " −62° 56′	$0.991011 + .005105 \sin^2\phi$	0.993563	10
84	123	" +79° 50′ " −62° 56′	$0.990918 + .005262 \sin^2\phi$	0.993549	11
mbining the above results			$0.990910 + .005290 \sin^2\phi$	0.993555	12

1 Laplace: "Traité de Mécanique Céleste," T. 2, livre 3, chap. 5, sect. 42.
2 Mathieu: "Sur les expériences du pendule;" in "Connaissance des Temps 1816." ditions, pp. 314–341, p. 332.
3 Biot et Arago: "Recueil d'Observations géodésiques, etc." Paris, 1821, p. 575.
4 Sabine: "An Account of Experiments to determine the Figure of the Earth, etc., by Edward Sabine." London, 1825, p. 352.
5 Saigey: "Comparaison des Observations du pendule à diverses latitudes; faites par M. Biot, Kater, Sabine, de Freycinet, et Duperry;" in "Bulletin des Sciences Mathématiques, etc.," T. 1, pp. 31–43, and 171–184. Paris, 1827.
6 Pontécoulant: "Théorie analytique du Système du monde," Paris, 1829, T. 2, p. 466.
7 Airy: "Figure of the Earth;" in "Encyc. Met." 2d Div. vol. 3, p. 230.
8 Poisson: "Traité de Mécanique," T. 1, p. 377; "Connaissance des Temps," 1834, 32–33; and Puissant: "Traité de géodésie," T. 2, p. 464.
9 Unferdinger: "Das Pendel als geodätisches Instrument;" in Grunert's "Archiv," 1869, 316.
10 Fischer: "Die Gestalt der Erde und die Pendelmessungen;" in "Ast. Nach." 1876, 87.
11 Helmert: "Die mathematischen und physikalischen Theorieen der höheren Geosie, von Dr. F. R. Helmert," II. Theil. Leipzig, 1884, p. 241.
12 Harkness.

e data here given with regard to the different determinations which have been made of the length of the pendulum are quoted from Harkness (Solar Parallax and its Related Constants, Washington, 1891).
culated from a logarithmic expression given by Unferdinger.

MISCELLANEOUS DATA WITH REGARD TO THE EARTH AND PLANETS.*

Length of the seconds pendulum at sea level $= l = 39.012540 + 0.208268 \sin^2\phi$ inches.
$= 3.251045 + 0.017356 \sin^2\phi$ feet.
$= 0.9909910 + 0.005290 \sin^2\phi$ metres.

Acceleration produced by gravity per second per second mean solar time . . . $= g = 32.086528 + 0.171293 \sin^2\phi$ feet.
$= 977.9886 + 5.2210 \sin^2\phi$ centimetres.

		Clarke Spheroid.	U. S. C. & G. Survey.
Equatorial radius	$= a =$ 6378206 metres; 3963.225 miles.		6378388 ± 18 metres; 3963.339 miles.
Polar semi-diameter	$= b =$ 6356584 metres; 3949.790 miles.		6356909 metres; 3949.992 miles.
Reciprocal of flattening	$= \frac{a}{a-b} = 295.0$		297.0 ± 0.5
Square of eccentricity	$= e^2 = \frac{a^2-b^2}{a^2} = 0.006768658$		0.0067237 ± 0.0000120.

Difference between geographical and geocentric latitude $= \phi - \phi' =$
$688.2242'' \sin 2\phi - 1.1482'' \sin 4\phi + 0.0026'' \sin 6\phi$.

Mean density of the Earth = 5.5247 ± 0.0013 (Burgess Phys. Rev. 1902).

Continental surface density of the Earth = 2.67
Mean density outer ten miles of earth's crust = 2.40 } Harkness.

Moments of inertia of the Earth; the principal moments being taken as A, B, and C, and C the greater:

$$\frac{C-A}{C} = 0.00326521 = \frac{1}{306.259};$$
$$C - A = 0.001064767\, Ea^2;$$
$$A = B = 0.325029\, Ea^2;$$
$$C = 0.326094\, Ea^2;$$

where E is the mass of the Earth and a its equatorial semidiameter.

Length of sidereal year = 365.2563578 mean solar days;
= 365 days 6 hours 9 minutes 9.314 seconds.

Length of tropical year $= 365.242199870 - 0.000006212\, \frac{t-1850}{100}$ mean solar days;
$= 365$ days 5 hours 48 minutes $\left(46.069 - 0.53675\, \frac{t-1850}{100}\right)$ seconds.

Length of sidereal month
$= 27.321661162 - 0.000000026240\, \frac{t-1800}{100}$ days;
$= 27$ days 7 hours 43 minutes $\left(11.524 - 0.022671\, \frac{t-1800}{100}\right)$ seconds.

Length of synodical month
$= 29.530588435 - 0.000000030696\, \frac{t-1800}{100}$ days;
$= 29$ days 12 hours 44 minutes $\left(2.841 - 0.026522\, \frac{t-1800}{100}\right)$ seconds.

Length of sidereal day = 86164.09965 mean solar seconds.

N. B. — The factor containing t in the above equations (the epoch at which the values of the quantities are required) may in all ordinary cases be neglected.

* Mostly from Harkness, "Solar Parallax and Allied Constants."

MISCELLANEOUS DATA WITH REGARD TO THE EARTH AND PLANETS.

Masses of the Planets.

Reciprocals of the masses of the planets relative to the sun and the mass of the moon relative to the Earth.

Mercury	= 6000000
Venus	= 408000
Earth *	= 329390
Mars	= 3093500
Jupiter	= 1047.35
Saturn	= 3501.6
Uranus	= 22869
Neptune	= 19700
Moon	= 81.45

Mean distance from earth to sun = 92900000 miles = 149500000 kilometres.

Eccentricity of the earth's orbit = e =

$$0.01675104 - 0.0000004180\,(t - 1900) - 0.000000126\left(\frac{t-1900}{100}\right)^2.$$

Solar parallax = 8.7997″ ± 0.003 (Weinberg, A. N. 165, 1904);
8.807 ± 0.0027 (Hinks, Eros, 7);
8.799 (Samson, Jupiter satellites; Harvard observations).

Lunar parallax = 3422.68″.

Mean distance from earth to moon = 60.2669 terrestrial radii;
= 238854 miles;
= 384393 kilometres.

Lunar inequality of the earth = L = 6.454″.

Parallactic inequality of the moon = Q = 124.80″.

Mean motion of moon's node in 365.25 days = $\mu = -19^\circ\,21'\,19.6191'' + 0.14136''\left(\frac{t-1800}{100}\right)$

Eccentricity and inclination of the moon's orbit = e_2 = 0.05490807.

Delaunay's $\gamma = \sin\frac{1}{2}I$ = 0.044886793.

$I = 5^\circ\,08'\,43.3546''$.

Constant of nutation = 9.2′.

Constant of aberration = 20.4962 ± 0.006 (Weinberg, l. c.).†

Time taken by light to traverse the mean radius of the earth's orbit
= 498.82 ± 0.1 seconds (Weinberg);
= 498.64 (Samson).

Velocity of light = 186330 miles per second (Weinberg);
= 299870 ± 0.03 kilometres per second.

General precession = 50.2564″ + 0.000222 (t — 1900).

Obliquity of the ecliptic = 23° 27′ 8.26″ — 0.4684 (t — 1900).

Gravitation constant = 666.07×10^{-10} cm^3/gr. sec^2 ± 0.16×10^{-10}.

* Earth + moon.

† Recent work of Doolittle's and others indicates a value not less than 20.51.

TERRESTRIAL MAGNETISM.

Secular Change of Declination.

Changes in the magnetic declination between 1810, the date of the earliest available observations, and 1910, for one or more places in each state and territory.

State.	Station.	1810	1820	1830	1840	1850	1860	1870	1880	1890	1900	1910
		°	°	°	°	°	°	°	°	°	°	°
Ala.	Montgomery	5.6E	5.8E	5.8E	5.6E	5.4E	5.0E	4.5E	3.9E	3.2E	2.8E	2.9E
Alas.	Sitka	–	–	–	–	–	28.7E	29.0E	29.3E	29.5E	29.7E	30.2E
	Kodiak	–	–	–	–	–	26.1E	25.6E	25.1E	24.7E	24.4E	24.1E
	Unalaska	–	–	–	–	–	20.4E	20.1E	19.6E	19.0E	18.3E	17.5E
	St. Michael	–	–	–	–	–	–	–	24.7E	23.1E	22.1E	21.4E
Ariz.	Holbrook	–	–	–	–	13.6E	13.7E	13.8E	13.7E	13.4E	13.5E	13.9E
	Prescott	–	–	–	–	13.3E	13.5E	13.7E	13.6E	13.5E	13.7E	14.3E
Ark.	Little Rock	8.6E	8.8E	9.0E	9.0E	8.8E	8.6E	8.2E	7.6E	7.0E	6.6E.	6.9E
Cal.	Los Angeles	12.1E	12.6E	13.2E	13.6E	14.0E	14.2E	14.4E	14.6E	14.6E	14.9E	15.5E
	San José	15.0E	15.5E	16.0E	16.4E	16.8E	17.1E	17.3E	17.5E	17.5E	17.8E	18.5E
Cal.	Redding	15.6E	16.1E	16.6E	17.0E	17.4E	17.8E	18.1E	18.2E	18.3E	18.6E	19.3E
Colo.	Pueblo	–	–	–	–	13.8E	13.8E	13.8E	13.5E	13.0E	12.9E	13.3E
	Glenwood Sp.	–	–	–	–	16.1E	16.2E	16.3E	16.1E	15.7E	15.6E	16.1E
Conn.	Hartford	5.1W	5.6W	6.1W	6.8W	7.5W	8.2W	8.7W	9.4W	9.8W	10.4W	11.0W
Del.	Dover	1.6W	1.9W	2.3W	2.8W	3.4W	4.0W	4.7W	5.3W	5.9W	6.4W	7.0W
D. C.	Washington	0.5E	0.3E	0.0	0.5W	1.0W	1.7W	2.4W	3.0W	3.6W	4.2W	4.7W
Fla.	Jacksonville	5.1E	5.1E	4.9E	4.6E	4.2E	3.7E	3.1E	2.4E	1.8E	1.3E	1.2E
	Pensacola	7.7E	7.8E	7.7E	7.5E	7.2E	6.8E	6.2E	5.6E	5.0E	4.5E	4.4E
	Tampa	6.4E	6.2E	5.9E	5.5E	5.0E	4.5E	3.9E	3.3E	2.8E	2.3E	2.0E
Ga.	Macon	5.9E	5.9E	5.7E	5.4E	5.0E	4.5E	3.9E	3.2E	2.6E	2.1E	2.0E
Haw.	Honolulu	–	–	–	–	9.4E	9.4E	9.5E	9.8E	10.1E	10.4E	10.6E
Idaho	Pocatello	–	–	–	–	17.4E	17.7E	17.8E	17.9E	17.7E	17.8E	18.4E
	Boise	–	–	–	–	18.0E	18.4E	18.6E	18.7E	18.6E	18.8E	19.4E
Ill.	Bloomington	6.3E	6.5E	6.6E	6.5E	6.3E	5.9E	5.4E	4.7E	4.1E	3.6E	3.4E
Ind.	Indianapolis	5.0E	5.1E	5.0E	4.7E	4.4E	3.8E	3.2E	2.6E	2.0E	1.4E	1.1E
Ia.	Des Moines	–	10.2E	10.4E	10.5E	10.4E	10.2E	9.7E	9.1E	8.4E	7.9E	8.1E
Kans.	Emporia	–	–	–	–	11.6E	11.5E	11.2E	10.7E	10.1E	9.8E	10.1E
	Ness City	–	–	–	–	12.4E	12.4E	12.2E	11.9E	11.4E	11.1E	11.4E
Ky.	Lexington	4.5E	4.5E	4.4E	4.1E	3.6E	3.1E	2.5E	1.9E	1.2E	0.7E	0.5E
	Princeton	6.8E	7.0E	7.0E	6.8E	6.5E	6.1E	5.6E	5.0E	4.3E	3.8E	3.7E
La.	Alexandria	8.4E	8.7E	8.8E	8.8E	8.7E	8.4E	8.0E	7.4E	6.9E	6.6E	6.8E
Me.	Eastport	13.6W	14.4W	15.2W	16.0W	17.0W	17.7W	18.2W	18.6W	18.7W	19.0W	19.4W
	Portland	9.0W	9.6W	10.3W	11.0W	11.6W	12.3W	12.8W	13.4W	13.9W	14.4W	14.8W
Md.	Baltimore	0.9W	1.1W	1.4W	1.9W	2.4W	3.1W	3.8W	4.4W	5.0W	5.6W	6.1W
Mass.	Boston	7.3W	7.8W	8.4W	9.1W	9.8W	10.5W	11.0W	11.5W	12.0W	12.6W	13.1W
Mass.	Pittsfield	5.7W	6.1W	6.7W	7.4W	8.1W	8.7W	9.3W	10.0W	10.4W	11.0W	11.5W
Mich.	Marquette	–	6.7E	6.7E	6.5E	6.0E	5.4E	4.6E	3.8E	3.0E	2.3E	2.0E
	Lansing	–	4.2E	4.1E	3.8E	3.3E	2.8E	2.1E	1.3E	0.5E	0.0E	0.4E
Minn.	Northome	–	10.4E	10.7E	10.8E	10.7E	10.4E	10.0E	9.3E	8.6E	8.0E	8.1E
	Mankato	–	11.3E	11.6E	11.7E	11.6E	11.3E	10.9E	10.4E	9.5E	9.0E	9.1E

* Tables have been compiled from United States Magnetic Tables and Magnetic Charts for 1905, published by the Coast and Geodetic Survey in 1908.

TERRESTRIAL MAGNETISM (*continued*).

Secular Change of Declination (*continued*).

State.	Station.	1810	1820	1830	1840	1850	1860	1870	1880	1890	1900	1910
		°	°	°	°	°	°	°	°	°	°	°
Miss.	Jackson	8.2E	8.4E	8.5E	8.4E	8.2E	7.9E	7.5E	6.9E	6.4E	6.0E	6.2E
Mo.	Sedalia	–	10.0E	10.2E	10.2E	10.1E	9.8E	9.4E	8.7E	8.0E	7.6E	7.9E
Mont.	Forsyth	–	–	–	18.2E	18.5E	18.6E	18.6E	18.4E	17.9E	17.8E	18.3E
	Helena	–	–	–	18.9E	19.3E	19.6E	19.8E	19.6E	19.4E	19.5E	20.0E
Nebr.	Hastings	–	11.6E	12.0E	12.1E	12.1E	12.0E	11.7E	11.2E	10.5E	10.2E	10.5E
Nebr.	Alliance	–	–	–	–	15.4E	15.4E	15.3E	14.8E	14.3E	14.2E	14.5E
Nev.	Elko	–	–	–	–	17.3E	17.6E	17.7E	17.7E	17.6E	17.8E	18.3E
	Hawthorne	–	–	–	–	16.3E	16.6E	16.9E	17.0E	17.0E	17.3E	17.8E
N. H.	Hanover	7.1W	7.5W	8.2W	8.9W	9.8W	10.5W	11.1W	11.6W	12.0W	12.5W	13.0W
N. J.	Trenton	2.8W	3.1W	3.5W	4.1W	4.7W	5.4W	6.0W	6.7W	7.2W	7.8W	8.4W
N. M.	Santa Rosa	–	–	–	–	12.7E	12.8E	12.7E	12.5E	12.1E	12.0E	12.4E
	Laguna	–	–	–	–	13.4E	13.6E	13.6E	13.4E	13.0E	13.0E	13.5E
N. Y.	Albany	5.6W	5.8W	6.3W	6.9W	7.6W	8.4W	9.1W	9.8W	10.2W	10.8W	11.4W
	Elmira	2.2W	2.4W	2.8W	3.3W	4.0W	4.8W	5.4W	6.3W	7.0W	7.6W	8.1W
N. C.	Newbern	1.7E	1.6E	1.3E	0.8E	0.3E	0.3W	1.0W	1.6W	2.2W	2.8W	3.3W
N. C.	Salisbury	3.9E	3.8E	3.6E	3.2E	2.7E	2.1E	1.5E	0.8E	0.2E	0.4W	0.7W
N. Dak.	Jamestown	–	–	–	–	14.5E	14.3E	14.0E	13.5E	12.7E	12.4E	12.8E
	Dickinson	–	–	–	–	17.6E	17.6E	17.4E	17.0E	16.4E	16.2E	16.6E
Ohio	Columbus	3.4E	3.4E	3.2E	2.9E	2.4E	1.8E	1.2E	0.6E	0.0	0.7W	1.1W
Okla.	Okmulgee	–	–	–	–	10.2E	10.1E	9.8E	9.4E	8.8E	8.5E	8.9E
Okla.	Enid	–	–	–	–	11.2E	11.1E	10.9E	10.5E	9.9E	9.7E	10.1E
Oreg.	Sumpter	–	–	–	–	19.3E	19.7E	20.0E	20.2E	20.2E	20.4E	21.0E
	Detroit	16.7E	17.4E	18.0E	18.6E	19.2E	19.7E	20.1E	20.4E	20.5E	20.8E	21.5E
Pa.	Philadelphia	2.2W	2.4W	2.8W	3.4W	4.1W	4.8W	5.5W	6.3W	6.8W	7.4W	8.0W
	Altoona	0.5W	0.6W	0.9W	1.3W	1.8W	2.4W	3.1W	3.8W	4.5W	5.1W	5.6W
P. R.	San Juan	–	–	–	–	–	–	–	–	–	1.0W	2.0W
R. I.	Newport	6.6W	7.1W	7.7W	8.4W	9.1W	9.8W	10.3W	10.8W	11.3W	11.9W	12.4W
S. C.	Columbia	4.4E	4.3E	4.1E	3.7E	3.2E	2.7E	2.1E	1.4E	0.8E	0.2E	0.1W
S. D.	Huron	–	–	–	13.1E	13.1E	12.9E	12.6E	12.1E	11.4E	11.1E	11.4E
	Rapid City	–	–	–	–	16.4E	16.4E	16.3E	15.8E	15.3E	15.1E	15.4E
Tenn.	Chattanooga	5.3E	5.3E	5.1E	4.8E	4.4E	3.9E	3.3E	2.6E	2.0E	1.5E	1.3E
	Huntington	–	7.4E	7.4E	7.3E	7.0E	6.6E	6.1E	5.5E	4.9E	4.4E	4.3E
Tex.	Houston	–	8.9E	9.2E	9.3E	9.3E	9.2E	8.9E	8.5E	7.9E	7.7E	8.1E
	San Antonio	–	–	9.6E	9.8E	9.9E	9.8E	9.6E	9.3E	8.9E	8.7E	9.1E
	Pecos	–	–	10.8E	11.0E	11.1E	11.1E	11.0E	10.8E	10.4E	10.3E	10.7E
Tex.	Floydada	–	–	–	–	11.3E	11.3E	11.2E	10.9E	10.4E	10.3E	10.7E
Utah	Salt Lake	–	–	–	–	16.4E	16.6E	16.7E	16.5E	16.3E	16.5E	17.0E
Vt.	Rutland	6.8W	7.2W	7.8W	8.5W	9.2W	10.0W	10.6W	11.2W	11.6W	12.1W	12.7W
Va.	Richmond	0.8E	0.6E	0.3W	0.1W	0.6W	1.2W	1.8W	2.5W	3.1W	3.7W	4.2W
	Lynchburg	1.9E	1.8E	1.6E	1.2E	0.8E	0.2E	0.5W	1.2W	1.8W	2.4W	2.8W
Wash.	Wilson Creek					21.3E	21.6E	21.9E	21.9E	22.1E	22.4E	22.9E
	Seattle	19.1E	19.7E	20.3E	20.8E	21.3E	21.8E	22.1E	22.3E	22.6E	23.0E	23.5E
W. Va.	Charleston	2.3E	2.2E	2.0E	1.6E	1.1E	0.5E	0.2W	0.9W	1.5W	2.1W	2.6W
Wis.	Madison	–	8.6E	8.7E	8.6E	8.3E	7.8E	7.2E	6.4E	5.6E	5.0E	4.9E
Wyo.	Douglas	–	–	–	–	15.8E	16.0E	16.0E	15.8E	15.4E	15.3E	15.7E
	Green River	–	–	–	–	16.8E	17.0E	17.0E	16.9E	16.6E	16.6E	17.0E

TERRESTRIAL MAGNETISM (*continued*).

TABLE 91.—Dip or Inclination.

This table gives for the epoch January 1, 1905, the values of the magnetic dip, I, corresponding to the longitudes west of Greenwich in the heading and the north latitudes in the first column.

	65°	70°	75°	80°	85°	90°	95°	100°	105°	110°	115°	120°	125°
°	°	°	°	°	°	°	°	°	°	°	°	°	°
19	–	–	48.8	49.1	47.5	46.3	44.8	44.2	43.9	–	–	–	–
21	–	–	51.0	51.1	50.0	49.3	48.2	47.0	46.5	–	–	–	–
23	–	–	53.7	53.0	52.4	51.8	50.7	49.6	48.8	48.2	–	–	–
25	–	–	56.3	56.0	55.0	54.5	53.2	52.4	51.5	50.6	49.8	48.3	–
27	–	–	58.9	58.1	57.6	56.8	55.6	54.7	53.9	53.1	52.6	51.0	–
29	–	60.7	61.0	60.2	59.8	58.9	58.2	57.2	56.2	55.5	54.8	53.7	–
31	–	63.0	63.1	62.6	62.0	61.3	60.6	59.6	58.7	57.7	56.7	56.0	–
33	–	65.0	65.0	64.6	64.0	63.5	62.7	62.0	61.0	59.8	58.9	58.1	–
35	–	67.0	66.9	66.5	66.0	65.6	64.9	63.7	62.7	62.3	61.0	60.2	–
37	–	68.6	68.9	68.6	68.2	67.7	66.9	66.2	65.1	64.6	62.9	62.2	–
39	–	70.3	70.6	70.4	70.2	69.7	68.8	68.1	67.2	66.1	65.0	64.0	62.8
41	–	71.8	72.2	72.2	71.9	71.4	70.8	69.8	68.9	67.8	66.8	65.6	64.7
43	–	73.5	73.9	74.1	73.8	73.3	72.6	71.6	70.7	69.6	68.6	67.5	66.3
45	74.4	74.8	75.6	75.5	75.4	75.0	74.3	73.6	72.4	71.5	70.3	69.2	68.1
47	75.7	76.2	76.9	76.8	76.9	76.8	76.0	75.2	74.2	73.0	71.8	70.8	69.9
49	76.8	78.1	78.2	78.3	78.7	78.1	77.5	76.8	75.8	74.5	73.5	72.3	71.4

TABLE 92.—Secular Change of Dip.

Values of magnetic dip for places designated by the north latitudes and longitudes west of Greenwich in the first two columns for January 1st of the years in the heading. The degrees are given in the third column and minutes in the succeeding columns.

Latitude.	Longitude.		1855	1860	1865	1870	1875	1880	1885	1890	1895	1900	1905	1910
°	°	°	′	′	′	′	′	′	′	′	′	′	′	′
25	80	55+	49	49	48	46	43	40	35	35	39	48	60	77
25	110	49+	08	20	30	39	46	55	61	68	76	86	96	106
30	83	60+	66	70	73	74	73	67	57	51	53	63	78	96
30	100	57+	44	49	58	67	70	65	60	61	68	77	90	105
30	115	54+	53	62	69	71	70	72	75	79	85	91	96	101
35	80	66+	57	58	57	54	45	35	26	21	20	22	30	38
35	90	65+	65	59	51	44	37	32	26	25	25	27	36	48
35	105	62+	–	–	–	32	30	24	24	24	28	34	42	50
35	120	60+	03	06	08	08	07	06	08	11	13	14	12	08
40	75	71+	82	82	78	73	65	55	43	33	27	24	24	24
40	90	70+	30	31	34	37	36	32	29	26	25	26	30	36
40	105	67+	–	–	–	56	53	51	51	51	52	56	60	65
40	120	64+	–	48	46	44	44	44	44	44	45	45	48	48
45	65	74+	116	110	101	92	80	68	57	46	35	28	24	20
45	75	75+	103	99	95	90	85	73	62	53	43	38	36	34
45	90	74+	81	81	81	79	77	75	68	63	61	59	60	60
45	105	72+	–	–	–	–	–	22	20	20	21	22	24	27
45	122.5	68+	35	34	37	40	40	39	37	34	30	26	24	20
49	92	78+	26	25	24	22	20	20	15	12	11	09	06	04
49	120	72+	–	26	24	22	22	19	20	19	19	19	18	16

TERRESTRIAL MAGNETISM (*continued*).

TABLE 93.—Horizontal Intensity.

This table gives for the epoch January 1, 1905, the horizontal intensity, H, expressed in C. G. S. units, corresponding to the longitudes in the heading and the latitudes in the first column.

	65°	70°	75°	80°	85°	90°	95°	100°	105°	110°	115°	120°	125°
°													
19	–	–	.307	.314	.319	.322	.328	.332	.331				
21	–	–	.301	.309	.314	.316	.320	.324	.324				
23	–	–	.293	.303	.305	.309	.312	.315	.317	.320			
25	–	–	.284	.292	.295	.299	.304	.307	.308	.309	.312	.304	
27	–	–	.274	.280	.286	.289	.296	.298	.300	.303	.306	.298	
29	–	.257	.262	.269	.276	.281	.286	.289	.292	.294	.297	.291	
31	–	.246	.251	.256	.263	.269	.274	.277	.282	.284	.285	.282	
33	–	.233	.239	.245	.251	.257	.262	.266	.270	.273	.274	.274	
35	–	.220	.225	.232	.240	.242	.248	.253	.256	.259	.262	.265	
37	–	.208	.209	.218	.222	.226	.232	.238	.245	.246	.252	.251	
39	–	.197	.198	.203	.206	.212	.217	.224	.229	.237	.240	.242	.245
41	–	.184	.185	.186	.192	.196	.202	.207	.216	.223	.228	.240	.236
43	–	.170	.170	.169	.175	.178	.187	.194	.201	.210	.215	.222	.226
45	.161	.157	.155	.156	.157	.162	.169	.177	.190	.192	.199	.208	.215
47	.145	.144	.140	.142	.142	.150	.152	.161	.170	.180	.188	.196	.201
49	.131	.129	.125	.126	.124	.129	.138	.146	.153	.165	.175	.182	.187

TABLE 94.—Secular Change of Horizontal Intensity.

Values of horizontal intensity in C. G. S. units for places designated by the latitude and longitude in the first two columns for January 1 of the years in the heading.

Latitude.	Longitude.	1855	1860	1865	1870	1875	1880	1885	1890	1895	1900	1905	1910
°	°												
25	80	.3099	.3086	.3073	.3057	.3042	.3025	.3008	.2990	.2970	.2949	.2920	.2890
25	110	.3229	.3218	.3204	.3189	.3170	.3155	.3143	.3130	.3117	.3104	.3090	.3075
30	83	.2803	.2795	.2788	.2780	.2772	.2763	.2752	.2740	.2725	.2706	.2680	.2644
30	100	–	–	.2961	.2942	.2924	.2907	.2891	.2877	.2865	.2850	.2830	.2804
30	115	.3040	.3026	.3011	.2996	.2979	.2964	.2952	.2940	.2929	.2920	.2910	.2898
35	80	.2384	.2379	.2374	.2369	.2367	.2363	.2359	.2352	.2347	.2337	.2320	.2296
35	90	–	–	–	.2462	.2462	.2461	.2458	.2455	.2447	.2437	.2430	.2399
35	105	–	–	–	–	.2620	.2608	.2599	.2590	.2583	.2573	.2560	.2544
35	120	–	–	–	.2720	.2707	.2695	.2683	.2672	.2663	.2656	.2650	.2644
40	75	.1880	.1883	.1891	.1902	.1911	.1919	.1925	.1930	.1931	.1928	.1920	.1909
40	90	–	.2086	.2082	.2079	.2076	.2075	.2074	.2072	.2068	.2060	.2050	.2036
40	105	–	–	–	.2272	.2266	.2261	.2257	.2253	.2248	.2240	.2230	.2217
40	120	–	–	–	.2429	.2420	.2412	.2406	.2399	.2392	.2386	.2380	.2379
45	65	.1504	.1514	.1525	.1537	.1553	.1567	.1578	.1589	.1600	.1608	.1610	.1610
45	75	.1483	.1485	.1488	.1495	.1506	.1516	.1527	.1538	.1546	.1550	.1550	.1554
45	90	–	.1635	.1633	.1631	.1628	.1626	.1624	.1623	.1624	.1623	.1620	.1616
45	105	–	–	–	.1920	.1919	.1918	.1916	.1913	.1910	.1906	.1900	.1892
45	122.5	.2175	.2170	.2162	.2153	.2145	.2135	.2127	.2121	.2117	.2115	.2115	.2115
49	92	.1332	.1330	.1328	.1324	.1321	.1319	.1318	.1318	.1321	.1324	.1330	.1335
49	120	.1841	.1841	.1840	.1839	.1836	.1831	.1826	.1821	.1819	.1820	.1820	.1824

TERRESTRIAL MAGNETISM (continued).

TABLE 95. — Total Intensity.

This table gives for the epoch January 1, 1905, the values of total intensity, F, expressed in C. G. S. units corresponding to the longitudes in the heading and the latitudes in the first column.

	65°	70°	75°	80°	85°	90°	95°	100°	105°	110°	115°	120°	125°
°													
19	–	–	.466	.480	.472	.466	.462	.463	.459	–	–	–	–
21	–	–	.478	.492	.489	.485	.480	.475	.471	–	–	–	–
23	–	–	.495	.504	.500	.500	.493	.486	.481	.480	–	–	–
25	–	–	.512	.522	.514	.515	.507	.503	.495	.487	.483	.457	–
27	–	–	.530	.530	.534	.528	.524	.516	.509	.505	.504	.474	–
29	–	.525	.540	.541	.549	.544	.543	.534	.525	.519	.515	.492	–
31	–	.542	.555	.556	.560	.560	.558	.547	.543	.531	.519	.504	–
33	–	.551	.566	.571	.572	.576	.571	.567	.557	.543	.530	.518	–
35	–	.563	.574	.582	.590	.586	.584	.571	.558	.557	.540	.533	–
37	–	.570	.581	.598	.598	.596	.591	.590	.582	.573	.553	.538	–
39	–	.584	.596	.605	.608	.611	.600	.600	.591	.585	.568	.552	.536
41	–	.589	.605	.608	.618	.614	.614	.600	.600	.590	.579	.581	.552
43	–	.599	.613	.617	.627	.619	.625	.614	.608	.602	.589	.580	.562
45	.599	.599	.623	.623	.623	.626	.624	.627	.628	.605	.590	.586	.576
47	.587	.604	.618	.622	.626	.657	.628	.630	.624	.616	.602	.596	.585
49	.574	.626	.611	.621	.633	.626	.638	.639	.624	.617	.616	.599	.588

TABLE 96. — Secular Change of Total Intensity.

Values of total intensity in C. G. S. units for places designated by the latitudes and longitudes in the first two columns for January 1 of the years in the heading. (Computed from Tables 92 and 94.)

Latitude.	Longitude.	1855	1860	1865	1870	1875	1880	1885	1890	1895	1900	1905	1910
°	°												
25	80	.5516	.5493	.5467	.5434	.5400	.5364	.5322	.5290	.5264	.5247	.5222	.5206
25	110	.4935	.4938	.4933	.4925	.4908	.4902	.4891	.4883	.4876	.4873	.4868	.4860
30	83	.5800	.5796	.5790	.5777	.5757	.5720	.5668	.5625	.5600	.5590	.5581	.5559
30	100	–	–	.5583	.5570	.5544	.5499	.5456	.5432	.5427	.5421	.5416	.5405
30	115	.5285	.5280	.5269	.5247	.5215	.5194	.5179	.5167	.5160	.5158	.5151	.5140
35	80	.6089	.6080	.6063	.6038	.5996	.5946	.5900	.5863	.5874	.5830	.5818	.5789
35	90	–	–	–	.5991	.5964	.5942	.5912	.5901	.5882	.5865	.5858	.5852
35	105	–	–	–	–	.5674	.5629	.5610	.5590	.5588	.5585	.5582	.5572
35	120	–	–	–	.5462	.5433	.5406	.5388	.5374	.5361	.5350	.5332	.5309
40	75	.6206	.6216	6220	.6227	.6212	.6182	.6136	.6098	.6070	.6045	.6019	.5985
40	90	–	.6254	.6258	.6264	.6250	.6226	.6208	.6187	.6170	.6151	.6141	.6135
40	105	–	–	–	.6048	.6019	.5997	.5986	.5976	.5967	.5963	.5953	.5940
40	120	–	–	–	.5691	.5670	.5651	.5637	.5620	.5608	.5593	.5590	.5591
45	65	.6188	.6186	.6167	.6152	.6134	.6107	.6077	.6048	.6019	.6005	.5987	.5962
45	75	.6454	.6431	.6413	.6404	.6412	.6363	.6327	.6306	.6266	.6247	.6233	.6235
45	90	–	.6465	.6457	.6434	.6408	.6386	.6330	.6291	.6382	.6264	.6259	.6244
45	105	–	–	–	–	–	.6332	.6314	.6303	.6299	.6392	.6284	.6275
45	122.5	.5956	.5938	.5930	.5918	.5896	.5864	.5834	.5804	.5776	.5754	.5745	.5728
49	92	.6643	.6624	.6604	.6566	.6533	.6523	.6472	.6445	.6451	.6447	.6450	.6456
49	120	–	.6100	.6085	.6071	.6061	.6028	.6017	.5995	.5988	.5992	.5986	.5988

AGONIC LINE.

The line of no declination appears to be still moving westward in the United States, but the line of no annual change is only a short distance to the west of it, so that it is probable that the extreme westerly position will soon be reached.

Lat. N.	Longitudes of the agonic line for the years—				
	1800	1850	1875	1890	1905
°	°	°	°	°	°
25	–	–	–	75.5	76.1
30	–	–	–	78.6	79.7
35	–	76.7	79.0	79.9	81.7
6	75.2	77.3	79.7	80.5	82.8
7	76.3	77.7	80.6	82.2	83.5
8	76.7	78.3	81.3	82.6	83.6
9	76.9	78.7	81.6	82.2	83.6
40	77.0	79.3	81.6	82.7	84.0
1	77.9	80.4	81.8	82.8	84.6
2	79.1	81.0	82.6	83.7	84.8
3	79.4	81.2	83.1	84.3	85.0
4	79.8	–	83.3	84.9	85.5
45	–	–	83.6	85.2	86.0
6	–	–	84.2	84.8	86.4
7	–	–	85.1	85.4	86.4
8	–	–	86.0	85.9	86.5
9	–	–	86.5	86.3	87.2

SMITHSONIAN TABLES.

PRESSURE OF COLUMNS OF MERCURY AND WATER.

British and metric measures. Correct at 0° C. for mercury and at 4° C. for water.

METRIC MEASURE.			BRITISH MEASURE.		
Cms. of Hg.	Pressure in grammes per sq. cm.	Pressure in pounds per sq. inch.	Inches of Hg.	Pressure in grammes per sq. cm.	Pressure in pounds per sq. inch.
1	13.5956	0.193376	1	34.533	0.491174
2	27.1912	0.386752	2	69.066	0.982348
3	40.7868	0.580128	3	103.598	1.473522
4	54.3824	0.773504	4	138.131	1.964696
5	67.9780	0.966880	5	172.664	2.455870
6	81.5736	1.160256	6	207.197	2.947044
7	95.1692	1.353632	7	241.730	3.438218
8	108.7648	1.547008	8	276.262	3.929392
9	122.3604	1.740384	9	310.795	4.420566
10	135.9560	1.933760	10	345.328	4.911740
Cms. of H_2O.	Pressure in grammes per sq. cm.	Pressure in pounds per sq. inch.	Inches of H_2O.	Pressure in grammes per sq. cm.	Pressure in pounds per sq. inch.
1	1	0.0142234	1	2.54	0.036127
2	2	0.0284468	2	5.08	0.072255
3	3	0.0426702	3	7.62	0.108382
4	4	0.0568936	4	10.16	0.144510
5	5	0.0711170	5	12.70	0.180637
6	6	0.0853404	6	15.24	0.216764
7	7	0.0995638	7	17.78	0.252892
8	8	0.1137872	8	20.32	0.289019
9	9	0.1280106	9	22.86	0.325147
10	10	0.1422340	10	25.40	0.361274

REDUCTION OF BAROMETRIC HEIGHT TO STANDARD TEMPERATURE.*

Corrections for brass scale and English measure.		Corrections for brass scale and metric measure.		Corrections for glass scale and metric measure.	
Height of barometer in inches.	a in inches for temp. F.	Height of barometer in mm.	a in mm. for temp. C.	Height of barometer in mm.	a in mm. for temp. C.
15.0	0.00135	**400**	0.0651	**50**	0.0086
16.0	.00145	410	.0668	100	.0172
17.0	.00154	420	.0684	150	.0258
17.5	.00158	430	.0700	200	.0345
18.0	.00163	440	.0716	250	.0431
18.5	.00167	450	.0732	300	.0517
19.0	.00172	460	.0749	350	.0603
19.5	.00176	470	.0765		
		480	.0781	**400**	0.0689
20.0	0.00181	490	.0797	450	.0775
20.5	.00185			500	.0861
21.0	.00190	**500**	0.0813	520	.0898
21.5	.00194	510	.0830	540	.0934
22.0	.00199	520	.0846	560	.0971
22.5	.00203	530	.0862	580	.1007
23.0	.00208	540	.0878		
23.5	.00212	550	.0894	**600**	0.1034
		560	.0911	610	.1051
24.0	0.00217	570	.0927	620	.1068
24.5	.00221	580	.0943	630	.1085
25.0	.00226	590	.0959	640	.1103
25.5	.00231			650	.1120
26.0	.00236	**600**	0.0975	660	.1137
26.5	.00240	610	.0992		
27.0	.00245	620	.1008	**670**	0.1154
27.5	.00249	630	.1024	680	.1172
		640	.1040	690	.1189
28.0	0.00254	650	.1056	700	.1206
28.5	.00258	660	.1073	710	.1223
29.0	.00263	670	.1089	720	.1240
29.2	.00265	680	.1105	730	.1258
29.4	.00267	690	.1121		
29.6	.00268			**740**	0.1275
29.8	.00270	**700**	0.1137	750	.1292
30.0	.00272	710	.1154	760	.1309
		720	.1170	770	.1327
30.2	0.00274	730	.1186	780	.1344
30.4	.00276	740	.1202	790	.1361
30.6	.00277	750	.1218	800	.1378
30.8	.00279	760	.1235		
31.0	.00281	770	.1251	**850**	0.1464
31.2	.00283	780	.1267	900	.1551
31.4	.00285	790	.1283	950	.1639
31.6	.00287	**800**	.1299	1000	.1723

*The height of the barometer is affected by the relative thermal expansion of the mercury and the glass, in the case of instruments graduated on the glass tube, and by the relative expansion of the mercury and the metallic inclosing case, usually of brass, in the case of instruments graduated on the brass case. This relative expansion is practically proportional to the first power of the temperature. The above tables of values of the coefficient of relative expansion will be found to give corrections almost identical with those given in the International Meteorological Tables. The numbers tabulated under a are the values of a in the equation $H_t = H_{t'} - a\,(t' - t)$ where H_t is the height at the standard temperature, $H_{t'}$ the observed height at the temperature t', and $a\,(t' - t)$ the correction for temperature. The standard temperature is 0° C. for the metric system and 28°.5 F. for the English system. The English barometer is correct for the temperature of melting ice at a temperature of approximately 28°.5 F., because of the fact that the brass scale is graduated so as to be standard at 62° F., while mercury has the standard density at 32° F.

EXAMPLE.—A barometer having a brass scale gave $H = 765$ mm. at 25° C.; required, the corresponding reading at 0° C. Here the value of a is the mean of .1235 and .1251, or .1243; $\therefore a\,(t' - t) = .1243 \times 25 = 3.11$. Hence $H_0 = 765 - 3.11 = 761.89$.

N. B.—Although a is here given to three and sometimes to four significant figures, it is seldom worth while to use more than the nearest two-figure number. In fact, all barometers have not the same values for a, and when great accuracy is wanted the proper coefficients have to be determined by experiment.

CORRECTION OF BAROMETER TO STANDARD GRAVITY.

Height above sea level in metres.	Observed height of barometer in millimetres.									
	400	450	500	550	600	650	700	750	800	
100							.014	.015	.016	
200							.028	.030	.032	
300							.041	.044	.047	
400	Correction in millimetres for elevation above sea level in first column and height of barometer in top line.						.055	.059	.063	
500						.064	.068	.073	.078	
600						.077	.082	.088		
700						.090	.096	.102		
800						.103	.109	.117		
900						.115	.123	.131		
1000				.108	.118	.128	.137	.146		
1100				.118	.130	.141	.150			
1200				.129	.142	.154	.164			
1300				.140	.153	.166	.178			
1400				.151	.165	.179	.191			
1500			.147	.162	.176	.191	.205			
1600			.157	.172	.188	.204				
1700			.167	.183	.200	.217				
1800			.177	.194	.212	.230			1.245	15000
1900			.187	.204	.224	.242			1.203	14500
2000		.176	.196	.215	.235	.255		1.340	1.162	14000
2100		.185	.206	.226	.247			1.292	1.120	13500
2200		.194	.216	.237	.259			1.244	1.088	13000
2300		.203	.226	.248	.271		1.345	1.196	1.046	12500
2400		.212	.236	.259	.283		1.291	1.149	1.004	12000
2500	.195	.220	.245	.270	.295		1.237	1.101	.962	11500
2600	.203	.229	.255			1.315	1.184	1.053	.920	11000
2700	.211	.238	.265			1.255	1.130	1.005	.879	10500
2800	.219	.247	.275			1.196	1.076	.957	.837	10000
2900	.227	.256	.285		1.050	1.136	1.022	.909	.795	9500
3000	.235	.265	.294		.984	1.076	.969	.861	.753	9000
3100	.243	.274			.918	1.016	.915	.813		8500
3200	.251	.283			.853	.957	.861	.765		8000
3300	.259	.292		1.077	.787	.897	.807			7500
3400	.267	.201		1.005	.721	.837	.753			7000
3500	.275	.309		.934	.655	.777	.700			6500
3600	.283			.862	.789	.718				6000
3700	.291			.790	.724	.658				5500
3800	.299		.779	.718	.658	.598				5000
3900	.307		.701	.646	.592					4500
4000	.314		.623	.574	.526					4000
			.545	.503	.461					3500
		.503	.467	.431	.395					3000
		.419	.389	.359						2500
	.359	.335	.311	.287						2000
	.269	.251	.233	.215						1500
.192	.179	.167	.155							1000
.096	.090	.084	.078							500
						Corrections in hundredths of an inch for elevation above sea level in last column and height of barometer in bottom line.				
32	30	28	26	24	22	20	18	16	14	Height above sea level in feet.
Observed height of barometer in inches.										

REDUCTION OF BAROMETER TO STANDARD GRAVITY.*

Reduction to Latitude 45°. — English Scale.

N. B. From latitude 0° to 44° the correction is to be subtracted.
From latitude 90° to 46° the correction is to be added.

Latitude.		Height of the barometer in inches.											
		19	20	21	22	23	24	25	26	27	28	29	30
		Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.
0°	90°	0.051	0.053	0.056	0.059	0.061	0.064	0.067	0.069	0.072	0.074	0.077	0.080
5	85	0.050	0.052	0.055	0.058	0.060	0.063	0.066	0.068	0.071	0.073	0.076	0.079
6	84	.049	.052	.055	.057	.060	.062	.065	.068	.070	.073	.076	.078
7	83	.049	.052	.054	.057	.059	.062	.065	.067	.070	.072	.075	.077
8	82	.049	.051	.054	.056	.059	.061	.064	.067	.069	.072	.074	.077
9	81	.048	.051	.053	.056	.058	.061	.063	.066	.068	.071	.073	.076
10	80	0.048	0.050	0.053	0.055	0.058	0.060	0.063	0.065	0.068	0.070	0.073	0.075
11	79	.047	.049	.052	.054	.057	.059	.062	.064	.067	.069	.072	.074
12	78	.046	.049	.051	.054	.056	.058	.061	.063	.066	.068	.071	.073
13	77	.045	.048	.050	.053	.055	.057	.060	.062	.065	.067	.069	.072
14	76	.045	.047	.049	.052	.054	.056	.059	.061	.063	.066	.068	.071
15	75	0.044	0.046	0.048	0.051	0.053	0.055	0.058	0.060	0.062	0.065	0.067	0.069
16	74	.043	.045	.047	.050	.052	.054	.056	.059	.061	.063	.065	.068
17	73	.042	.044	.046	.049	.051	.053	.055	.057	.060	.062	.064	.066
18	72	.041	.043	.045	.047	.050	.052	.054	.056	.058	.060	.062	.065
19	71	.040	.042	.044	.046	.048	.050	.052	.055	.057	.059	.061	.063
20	70	0.039	0.041	0.043	0.045	0.047	0.049	0.051	0.053	0.055	0.057	0.059	0.061
21	69	.038	.040	.042	.044	.045	.047	.049	.051	.053	.055	.057	.059
22	68	.036	.038	.040	.042	.044	.046	.048	.050	.052	.054	.056	.057
23	67	.035	.037	.039	.041	.043	.044	.046	.048	.050	.052	.054	.055
24	66	.034	.036	.037	.039	.041	.043	.045	.046	.048	.050	.052	.053
25	65	0.033	0.034	0.036	0.038	0.039	0.041	0.043	0.044	0.046	0.048	0.050	0.051
26	64	.031	.033	.034	.036	.038	.039	.041	.043	.044	.046	.048	.049
27	63	.030	.031	.033	.034	.036	.038	.039	.041	.042	.044	.045	.047
28	62	.028	.030	.031	.033	.034	.036	.037	.039	.040	.042	.043	.045
29	61	.027	.028	.030	.031	.032	.034	.035	.037	.038	.039	.041	.042
30	60	0.025	0.027	0.028	0.029	0.031	0.032	0.033	0.035	0.036	0.037	0.039	0.040
31	59	.024	.025	.026	.027	.029	.030	.031	.032	.034	.035	.036	.037
32	58	.022	.023	.025	.026	.027	.028	.029	.030	.032	.033	.034	.035
33	57	.021	.022	.023	.024	.025	.026	.027	.028	.029	.030	.031	.032
34	56	.019	.020	.021	.022	.023	.024	.025	.026	.027	.028	.029	.030
35	55	0.017	0.018	0.019	0.020	0.021	0.022	0.023	0.024	0.025	0.025	0.026	0.027
36	54	.016	.016	.017	.018	.019	.020	.021	.021	.022	.023	.024	.025
37	53	.014	.015	.015	.016	.017	.018	.018	.019	.020	.021	.021	.022
38	52	.012	.013	.014	.014	.015	.015	.016	.017	.017	.018	.019	.019
39	51	.011	.011	.012	.012	.013	.013	.014	.014	.015	.015	.016	.017
40	50	0.009	0.009	0.010	0.010	0.011	0.011	0.012	0.012	0.012	0.013	0.013	0.014
41	49	.007	.007	.008	.008	.009	.009	.009	.010	.010	.010	.011	.011
42	48	.005	.006	.006	.006	.006	.007	.007	.007	.008	.008	.008	.008
43	47	.004	.004	.004	.004	.004	.004	.005	.005	.005	.005	.005	.006
44	46	.002	.002	.002	.002	.002	.002	.002	.002	.003	.003	.003	.003

* "Smithsonian Meteorological Tables," p. 58.

REDUCTION OF BAROMETER TO STANDARD GRAVITY.*

Reduction to Latitude 45°. — Metric Scale.

N. B. — From latitude 0° to 44° the correction is to be subtracted.
From latitude 90° to 46° the correction is to be added.

Latitude.		Height of the barometer in millimetres.											
		520	560	600	620	640	660	680	700	720	740	760	780
		mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
0°	90°	1.38	1.49	1.60	1.65	1.70	1.76	1.81	1.86	1.92	1.97	2.02	2.08
5	85	1.36	1.47	1.57	1.63	1.68	1.73	1.81	1.84	1.89	1.94	1.99	2.04
6	84	1.35	1.46	1.56	1.61	1.67	1.72	1.78	1.82	1.87	1.93	1.98	2.03
7	83	1.34	1.45	1.55	1.60	1.65	1.70	1.77	1.81	1.86	1.91	1.96	2.01
8	82	1.33	1.43	1.54	1.59	1.64	1.69	1.76	1.79	1.84	1.89	1.94	2.00
9	81	1.32	1.42	1.52	1.57	1.62	1.67	1.74	1.77	1.82	1.87	1.92	1.97
10	80	1.30	1.40	1.50	1.55	1.60	1.65	1.70	1.75	1.80	1.85	1.90	1.95
11	79	1.28	1.38	1.48	1.53	1.58	1.63	1.68	1.73	1.78	1.83	1.88	1.93
12	78	1.26	1.36	1.46	1.51	1.56	1.60	1.65	1.70	1.75	1.80	1.85	1.90
13	77	1.24	1.34	1.44	1.48	1.53	1.58	1.63	1.67	1.72	1.77	1.82	1.87
14	76	1.22	1.32	1.41	1.46	1.50	1.55	1.60	1.65	1.69	1.74	1.79	1.83
15	75	1.20	1.29	1.38	1.43	1.48	1.52	1.57	1.61	1.66	1.71	1.75	1.80
16	74	1.17	1.26	1.35	1.40	1.44	1.49	1.54	1.58	1.63	1.67	1.72	1.76
17	73	1.15	1.24	1.32	1.37	1.41	1.45	1.50	1.54	1.59	1.63	1.68	1.72
18	72	1.12	1.21	1.29	1.34	1.38	1.42	1.46	1.51	1.55	1.59	1.64	1.68
19	71	1.09	1.17	1.26	1.30	1.34	1.38	1.43	1.47	1.51	1.55	1.59	1.64
20	70	1.06	1.14	1.22	1.26	1.31	1.35	1.39	1.43	1.47	1.51	1.55	1.59
21	69	1.03	1.11	1.19	1.23	1.27	1.31	1.35	1.38	1.42	1.46	1.50	1.54
22	68	1.00	1.07	1.15	1.19	1.23	1.26	1.30	1.34	1.38	1.42	1.46	1.49
23	67	0.96	1.04	1.11	1.15	1.18	1.22	1.26	1.29	1.33	1.37	1.41	1.44
24	66	.93	1.00	1.07	1.10	1.14	1.18	1.21	1.25	1.28	1.32	1.35	1.39
25	65	0.89	0.96	1.03	1.06	1.10	1.13	1.16	1.20	1.23	1.27	1.30	1.33
26	64	.85	.92	0.98	1.02	1.05	1.08	1.11	1.15	1.18	1.21	1.25	1.28
27	63	.81	.88	.94	0.97	1.00	1.03	1.06	1.10	1.13	1.16	1.19	1.22
28	62	.77	.83	.89	.92	0.95	0.98	1.01	1.04	1.07	1.10	1.13	1.16
29	61	.73	.79	.85	.87	.90	.93	0.96	0.99	1.02	1.04	1.07	1.10
30	60	0.69	0.75	0.80	0.83	0.85	0.88	0.91	0.94	0.96	0.98	1.01	1.04
31	59	.65	.70	.75	.77	.80	.82	.85	.87	.90	.92	0.95	0.97
32	58	.61	.65	.70	.72	.75	.77	.79	.82	.84	.86	.89	.91
33	57	.56	.61	.65	.67	.69	.71	.74	.76	.78	.80	.82	.84
34	56	.52	.56	.60	.62	.64	.66	.68	.70	.72	.74	.76	.78
35	55	0.47	0.51	0.55	0.56	0.58	0.60	0.62	0.64	0.66	0.67	0.69	0.71
36	54	.43	.46	.49	.51	.53	.54	.56	.58	.59	.61	.63	.64
37	53	.38	.41	.44	.45	.47	.48	.50	.51	.53	.54	.56	.57
38	52	.33	.36	.39	.40	.41	.43	.44	.45	.46	.48	.49	.50
39	51	.29	.31	.33	.34	.35	.37	.38	.39	.40	.41	.42	.43
40	50	0.24	0.26	0.28	0.29	0.30	0.31	0.31	0.32	0.33	0.34	0.35	0.36
41	49	.19	.21	.22	.23	.24	.24	.25	.26	.27	.27	.28	.29
42	48	.14	.16	.17	.17	.18	.18	.19	.19	.20	.21	.21	.22
43	47	.10	.10	.11	.12	.12	.12	.13	.13	.13	.14	.14	.14
44	46	.05	.05	.06	.06	.06	.06	.06	.07	.07	.07	.07	.07

* "Smithsonian Meteorological Tables," p. 59.

CORRECTION OF THE BAROMETER FOR CAPILLARITY.*

1. METRIC MEASURE.

Diameter of tube in mm.	Height of Meniscus in Millimetres.							
	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8
	Correction to be added in millimetres.							
4	0.83	1.22	1.54	1.98	2.37	–	–	–
5	.47	0.65	0.86	1.19	1.45	1.80	–	–
6	.27	.41	.56	0.78	0.98	1.21	1.43	–
7	.18	.28	.40	.53	.67	0.82	0.97	1.13
8	–	.20	.29	.38	.46	.56	.65	0.77
9	–	.15	.21	.28	.33	.40	.46	.52
10	–	–	.15	.20	.25	.29	.33	.37
11	–	–	.10	.14	.18	.21	.24	.27
12	–	–	.07	.10	.13	.15	.18	.19
13	–	–	.04	.07	.10	.12	.13	.14

2. BRITISH MEASURE.

Diameter of tube in inches.	Height of Meniscus in Inches.							
	.01	.02	.03	.04	.05	.06	.07	.08
	Correction to be added in hundredths of an inch.							
.15	2.36	4.70	6.86	9.23	11.56	–	–	–
.20	1.10	2.20	3.28	4.54	5.94	7.85	–	–
.25	0.55	1.20	1.92	2.76	3.68	4.72	5.88	–
.30	.36	0.79	1.26	1.77	2.30	2.88	3.48	4.20
.35	–	.51	0.82	1.15	1.49	1.85	2.24	2.65
.40	–	.40	.61	0.81	1.02	1.22	1.42	1.62
.45	–	–	.32	.51	0.68	0.83	0.96	1.15
.50	–	–	.20	.35	.47	.56	.64	0.71
.55	–	–	.08	.20	.31	.40	.47	.52

* The first table is from Kohlrausch (Experimental Physics), and is based on the experiments of Mendelejeff and Gutkowski (Jour. de Phys. Chem. Geo. Petersburg, 1877, or Wied. Beib. 1867). The second table has been calculated from the same data by conversion into inches and graphic interpolation.

A number of tables, mostly based on theoretical formulæ and the capillary constants of mercury in glass tubes in air and vacuum, were given in the fourth edition of Guyot's Tables, and may be there referred to. They are not repeated here, as the above is probably more accurate, and historical matter is excluded for convenience in the use of the book.

AERODYNAMICS.

The pressure on a plane surface normal to the wind is for ordinary wind velocities expressed by

$$P = kwav^2$$

where k is a constant depending on the units employed, w the mass of unit volume of the air, a the area of the surface and v the velocity of the wind.* Engineers generally use the table of values of P given by Smeaton in 1759. This table was calculated from the formula

$$P = .00492\, v^2$$

and gives the pressure in pounds per square foot when v is expressed in miles per hour. The corresponding formula when v is expressed in feet per second is

$$P = .00228\, v^2.$$

Later determinations do not agree well together, but give on the average somewhat lower values for the coefficient. The value of w depends, of course, on the temperature and the barometric pressure. Langley's experiments give $kw = .00166$ at ordinary barometric pressure and 10° C. temperature.

For planes inclined at an angle α less than 90° to the direction of the wind the pressure may be expressed as $P_\alpha = F_\alpha P_{90}$.

Table 104, founded on the experiments of Langley, gives the value of F_α for different values of α. The word *aspect*, in the headings, is used by him to define the position of the plane relative to the direction of motion. The numerical value of the aspect is the ratio of the linear dimension transverse to the direction of motion to the linear dimension, a vertical plane through which is parallel to the direction of motion.

TABLE 104.—Values of F_α in Equation $P_\alpha = F_\alpha P_{90}$.

Plane 30 in. × 4.8 in. Aspect 6 (nearly).		Plane 12 in. × 12 in. Aspect 1.		Plane 6 in. × 24 in. Aspect ¼.	
α	F_α	α	F_α	α	F_α
0°	0.00	0°	0.00	0°	0.00
5	0.28	5	0.15	5	0.07
10	0.44	10	0.30	10	0.17
15	0.55	15	0.44	15	0.29
20	0.62	20	0.57	20	0.43
25	0.66	25	0.69	25	0.58
30	0.69	30	0.78	30	0.71
35	0.72	35	0.84	–	–
40	0.74	40	0.88	–	–
45	0.76	45	0.91	–	–
50	0.78	50	–	–	–

* The following pressures in pounds per square inch show roughly the influence of the shape and size of the resisting surface (Dines' results). The wind velocity was 20.9 miles per hour. The flat plates were ⅛ in. thick.

Square, sides 4 in.	1.51	Plate, 6 in. diam. 90° cone at back	1.49
Circle, same area	1.51	Same, cone in front	0.98
Rectangle, 16 in. by 1	1.70	" sharp 30° cone at back	1.54
Square, 12 in. sides	1.57	" cone in front	0.60
Circle, same area	1.55	5 in. Robinson cup on 8¾ in. of ⅛ in. rod	1.68
Rectangle, 24 in. by 6	1.59	Same, with back to wind	0.73
Square, sides 16 in.	1.52	9 in. cup on 6½ in. of ⅛ in. rod	1.75
Plate, 6 in. diam. 4¾ thick	1.45	Same, with back to wind	0.60
Ditto, curved side to wind	0.92	2½ in. cup on 9¾ in. of ¼ in. rod	2.60
Sphere, 6 in. diam.	0.67	Same, with back to wind	1.04

AERODYNAMICS.

On the basis of the results given in Table 104 Langley states the following condition for the soaring of an aeroplane 76.2 centimetres long and 12.2 centimetres broad, weighing 500 grammes. —that is, a plane one square foot in area, weighing 1.1 pounds. It is supposed to soar in a horizontal direction, with aspect 6.

TABLE 105.— Data for the Soaring of Planes 76.2 × 12.2 cms. weighing 500 Grammes, Aspect 6.

Inclination to the horizontal α.	Soaring speed v.		Work expended per minute (activity).		Weight of planes of like form, capable of soaring at speed v with the expenditure of one horse power.	
	Metres per sec.	Feet per sec.	Kilogramme metres.	Foot pounds.	Kilogrammes.	Pounds.
2°	20.0	66	24	174	95.0	209
5	15.2	50	41	297	55.5	122
10	12.4	41	65	474	34.8	77
15	11.2	37	86	623	26.5	58
30	10.6	35	175	1268	13.0	29
45	11.2	37	336	2434	6.8	15

$$\text{In general, if } \rho = \frac{\text{weight}}{\text{area}}$$

$$\text{Soaring speed } v = \sqrt{\frac{\rho}{k} \frac{1}{F_\alpha \cos \alpha}}$$

$$\text{Activity per unit of weight} = v \tan \alpha$$

The following data for curved surfaces are due to Wellner (Zeits. für Luftschifffahrt, x., Oct. 1893).

Let the surface be so curved that its intersection with a vertical plane parallel to the line of motion is a parabola whose height is about $\frac{1}{12}$ the subtending chord, and let the surface be bounded by an elliptic outline symmetrical with the line of motion. Also, let the angle of inclination of the chord of the surface be α, and the angle between the direction of resultant air pressure and the normal to the direction of motion be β. Then $\beta < \alpha$, and the soaring speed is $v = \sqrt{\frac{\rho}{k} \frac{1}{F_\alpha \cos \beta}}$, while the activity per unit of weight $= v \tan \beta$.

The following series of values were obtained from experiments on moving trains and in the wind.

Angle of inclination α =	−3°	0°	+3°	6°	9°	12°
Inclination factor F_α =	0.20	0.50	0.75	0.90	1.00	1.05
$\tan \beta$ =	0.01	0.02	0.03	0.04	0.10	0.17

Thus a curved surface shows finite soaring speeds when the angle of inclination α is zero or even slightly negative. Above $\alpha = 12°$ curved surfaces rapidly lose any advantage they may have for small inclinations.

FRICTION.

The following table of coefficients of friction f and its reciprocal $1/f$, together with the angle of friction or angle of repose ϕ, is quoted from Rankine's "Applied Mechanics." It was compiled by Rankine from the results of General Morin and other authorities, and is sufficient for all ordinary purposes.

Material.	f	$1/f$	ϕ
Wood on wood, dry	.25–.50	4.00–2.00	14.0–26.5
" " " soapy	.20	5.00	11.5
Metals on oak, dry	.50–.60	2.00–1.67	26.5–31.0
" " " wet	.24–.26	4.17–3.85	13.5–14.5
" " " soapy	.20	5.00	11.5
" " elm, dry	.20–.25	5.00–4.00	11.5–14.0
Hemp on oak, dry	.53	1.89	28.0
" " " wet	.33	3.00	18.5
Leather on oak	.27–.38	3.70–2.86	15.0–19.5
" " metals, dry	.56	1.79	29.5
" " " wet	.36	2.78	20.0
" " " greasy	.23	4.35	13.0
" " " oily	.15	6.67	8.5
Metals on metals, dry	.15–.20	6.67–5.00	8.5–11.5
" " " wet	.3	3.33	16.5
Smooth surfaces, occasionally greased	.07–.08	14.3–12.50	4.0–4.5
" " continually greased	.05	20.00	3.0
" " best results	.03–.036	33.3–27.6	1.75–2.0
Steel on agate, dry *	.20	5.00	11.5
" " " oiled *	.107	9.35	6.1
Iron on stone	.30–.70	3.33–1.43	16.7–35.0
Wood on stone	About .40	2.50	22.0
Masonry and brick work, dry	.60–.70	1.67–1.43	33.0–35.0
" " " " damp mortar	.74	1.35	36.5
" on dry clay	.51	1.96	27.0
" " moist clay	.33	3.00	18.25
Earth on earth	.25–1.00	4.00–1.00	14.0–45.0
" " " dry sand, clay, and mixed earth	.38–.75	2.63–1.33	21.0–37.0
" " " damp clay	1.00	1.00	45.0
" " " wet clay	.31	3.23	17.0
" " " shingle and gravel	.81–1.11	1.23–0.9	39.0–48.0

* Quoted from a paper by Jenkin and Ewing, "Phil. Trans. R. S." vol. 167. In this paper it is shown that in cases where "static friction" exceeds "kinetic friction" there is a gradual increase of the coefficient of friction as the speed is reduced towards zero.

VISCOSITY.

The coefficient of viscosity is the tangential force per unit area of one face of a plate of the fluid which is required to keep up unit distortion between the faces. Viscosity is thus measured in terms of the temporary rigidity which it gives to the fluid. Solids may be included in this definition when only that part of the rigidity which is due to varying distortion is considered. One of the most satisfactory methods of measuring the viscosity of fluids is by the observation of the rate of flow of the fluid through a capillary tube, the length of which is great in comparison with its diameter. Poiseuille * gave the following formula for calculating the viscosity coefficient in this case: $\mu = \frac{\pi h r^4 s}{8vl}$, where h is the pressure height, r the radius of the tube, s the density of the fluid, v the quantity flowing per unit time, and l the length of the capillary part of the tube. The liquid is supposed to flow from an upper to a lower reservoir joined by the tube, hence h and l are different. The product hs is the pressure under which the flow takes place. Hagenbach † pointed out that this formula is in error if the velocity of flow is sensible, and suggested a correction which was used in the calculation of his results. The amount to be subtracted from h, according to Hagenbach, is $\frac{v^2}{\sqrt{2} \cdot g}$, where g is the acceleration due to gravity. Gartenmeister ‡ points out an error in this to which his attention had been called by Finkener, and states that the quantity to be subtracted from h should be simply $\frac{v^2}{g}$; and this formula is used in the reduction of his observations. Gartenmeister's formula is the most accurate, but all of them nearly agree if the tube be long enough to make the rate of flow very small. None of the formulæ take into account irregularities in the distortion of the fluid near the ends of the tube, but this is probably negligible in all cases here quoted from, although it probably renders the results obtained by the "viscosimeter" commonly used for testing oils useless for our purpose.

The term "specific viscosity" is sometimes used in the headings of the tables; it means the ratio of the viscosity of the fluid under consideration to the viscosity of water at a specified temperature.

The friction of a fluid is proportional to the size of the rubbing surface, to $\frac{dv}{dx}$, where v is the velocity of motion in a direction perpendicular to the rubbing surface, and to a constant known as the viscosity.

Variation of Viscosity of Water, with Temperature. Dynes per sq. cm.

Temp. C.	Poiseville. 1846.	Sprung. 1876.	Slotte. 1883.	Thorpe-Rogers. 1894. §	Specific viscosity.	Temp. C.	Slotte. 1883.	Thorpe-Rogers. 1894.	Specific Viscosity.
0°	0.01716	0.01778	0.01808	0.01778	1.000	55°	0.00510	0.00506	.285
5	.01515	.01510	.01524	.01510	.849	60	.00472	.00468	.263
10	.01309	.01301	.01314	.01303	.733	65	.00438	.00436	.245
15	.01146	.01135	.01144	.01134	.638	70	.00408	.00406	.228
20	.01008	.01003	.01008	.01002	.564	75	.00382	.00380	.214
25	.00897	.00896	.00896	.00891	.501	80	.00358	.00356	.200
30	.00803	.00802	.00803	.00798	.449	85	.00337	.00335	.188
35	.00721	.00723	.00724	.00720	.405	90	.00318	.00316	.178
40	.00653	.00657	.00657	.00654	.368	95	.00301	.00299	.168
45	.00595	.00602	.00602	.00597	.336	100	.00285	.00283	.159
50	–	.00553	.00553	.00548	.308				

* "Comptes rendus," vol. 15, 1842; "Mém. Serv. Étr." 1846.

† "Pogg. Ann." vol. 109, 1860.

‡ "Zeitschr. Phys. Chem." vol. 6, 1890.

§ Thorpe and Rogers, "Philos. Trans." 185A, 1894; "Proc. Roy. Soc." 55, 1894.

VISCOSITY.

TABLE 108. — Solution of Alcohol in Water.*

Coefficients of viscosity, in C. G. S. units, for solution of alcohol in water.

Temp. C.	Percentage by weight of alcohol in the mixture.								
	0	8.21	16.60	34.58	43.99	53.36	75.75	87.45	99.72
0°	0.0181	0.0287	0.0453	0.0732	0.0707	0.0632	0.0407	0.0294	0.0180
5	.0152	.0234	.0351	.0558	.0552	.0502	.0344	.0256	.0163
10	.0131	.0195	.0281	.0435	.0438	.0405	.0292	.0223	.0148
15	.0114	.0165	.0230	.0347	.0353	.0332	.0250	.0195	.0134
20	.0101	.0142	.0193	.0283	.0286	.0276	.0215	.0172	.0122
25	0.0090	0.0123	0.0163	0.0234	0.0241	0.0232	0.0187	0.0152	0.0110
30	.0081	.0108	.0141	.0196	.0204	.0198	.0163	.0135	.0100
35	.0073	.0096	.0122	.0167	.0174	.0171	.0144	.0120	.0092
40	.0067	.0086	.0108	.0143	.0150	.0149	.0127	.0107	.0084
45	.0061	.0077	.0095	.0125	.0131	.0130	.0113	.0097	.0077
50	0.0056	0.0070	0.0085	0.0109	0.0115	0.0115	0.0102	0.0088	0.0070
55	.0052	.0063	.0076	.0096	.0102	.0102	.0091	.0086	.0065
60	.0048	.0058	.0069	.0086	.0091	.0092	.0083	.0073	.0060

The following tables (152-153) contain the results of a number of experiments in the viscosity of mineral oils derived from petroleum residues and used for lubricating purposes.†

TABLE 109. — Mineral Oils.‡

Density.	Flashing point. ° C.	Burning point. ° C.	Sp. viscosity. Water at 20° C. = 1. 20° C.	50° C.	100° C.
.931	243	274	–	11.30	2.9
.921	216	246	–	7.31	2.5
.906	189	208	–	3.45	1.5
.921	163	190	–	27.80	2.8
.917	132	168	–	–	2.6
.904	170	207	8.65	2.65	1.7
.891	151	182	4.77	1.86	1.3
.878	108	148	2.94	1.48	–
.855	42	45	1.65	–	–
.905	165	202	–	3.10	1.5
.894	139	270	7.60	3.60	1.3
.866	90	224	2.50	1.50	–

TABLE 110. — Oils.

Oil.	Density.	Flashing point. ° C.	Burning point. ° C.	Viscosity at 19° C., water at 19° C. = 1.
Cylinder oil . .	.917	227	274	191
Machine oil . .	.914	213	260	102
Wagon oil . .	.914	148	182	80
" " . .	.911	157	187	70
Naphtha residue	.910	134	162	55
Oleo-naphtha .	.910	219	257	121
" " .	.904	201	242	66
" " .	.894	184	222	26
Oleonid . . .	.884	185	217	28
" best quality	.881	188	224	20
Olive oil . . .	.916	–	–	22
Whale oil . .	.879	–	–	9
" " . .	.875	–	–	8

* This table was calculated from the table of fluidities given by Noack (Wied. Ann. vol. 27, p. 217), and shows a maximum for a solution containing about 40 per cent of alcohol. A similar result was obtained for solutions of acetic acid.

† Table 152 is from a paper by Engler in Dingler's "Poly. Jour." vol. 268, p. 76, and Table 153 is from a paper by Lamansky in the same journal, vol. 248, p. 29. The very mixed composition of these oils renders the viscosity a very uncertain quantity, neither the density nor the flashing point being a good guide to viscosity.

‡ The different groups in this table are from different residues.

VISCOSITY.

This table gives some miscellaneous data as to the viscosity of liquids, mostly referring to oils and paraffins. The viscosities are in C. G. S. units.

Liquid.	G. %	Coefficient of viscosity.	Temp. Cent.°	Authority.
Ammonia		0.0160	11.9	Poiseuille.
"		0.0149	14.5	"
Anisol		0.0111	20.0	Gartenmeister.
Glycerine		42.20	2.8	Schottner.
"		25.18	8.1	"
"		13.87	14.3	"
"		8.30	20.3	"
"		4.94	26.5	"
Glycerine and water	94.46	7.437	8.5	"
" "	80.31	1.021	8.5	"
" "	64.05	0.222	8.5	"
" "	49.79	0.092	8.5	"
Glycol		0.0219	0.0	Arrhenius.
Mercury*		0.0184	—20	Koch.
"		0.0170	0.0	"
"		0.0157	20.0	"
"		0.0122	100.0	"
"		0.0102	200.0	"
"		0.0093	300.0	"
Meta-cresol		0.1878	20.0	Gartenmeister.
Olive oil		0.9890	15.0	Brodmann.
Paraffins: Decane		0.0077	22.3	Bartolli & Stracciati.
Dodecane		0.0126	23.3	" "
Heptane		0.0045	24.0	" "
Hexadecane		0.0359	22.2	" "
Hexane		0.0033	23.7	" "
Nonane		0.0062	22.3	" "
Octane		0.0053	22.2	" "
Pentane		0.0026	21.0	" "
Pentadecane		0.0281	22.0	" "
Tetradecane		0.0213	21.9	" "
Tridecane		0.0155	23.3	" "
Undecane		0.0095	22.7	" "
Petroleum (Caucasian)		0.0190	17.5	Petroff.
Rape oil		25.3	0.0	O. E. Meyer.
" "		3.85	10.0	"
" "		1.63	20.0	"
" "		0.96	30.0	"

* Calculated from the formula $\mu = .017 - .000066t + .0000021t^2 - .00000000025t^3$ (vide Koch, Wied. Ann. vol. 14. p. 1).

VISCOSITY.

This table gives the viscosity of a number of liquids together with their temperature variation. The headings are temperatures in Centigrade degrees, and the numbers under them the coefficients of viscosity in C. G. S. units.*

Liquid.	Temperature Centigrade.								Reference.
	0°	10°	20°	30°	40°	50°	70°	90°	
Acetates: Methyl	–	.0046	.0041	.0036	.0032	.0030	–	–	1
Ethyl	–	.0051	.0044	.0040	.0035	.0032	–	–	1
Propyl	–	.0066	.0059	.0052	.0044	.0039	–	–	1
Allyl	–	.0068	.0061	.0054	.0049	.0044	–	–	1
Amyl	–	.0106	.0089	.0077	.0065	.0058	–	–	1
Acids: Formic	–	.02262	.01804	.01465	.01224	.01025	–	–	2
Acetic	–	.0150	.0126	.0109	.0094	.0082	–	–	1
Propionic	–	.0125	.0107	.0092	.0081	.0073	–	–	3
"	–	.0139	.0118	.0101	.0091	.0080	–	–	1
Butyric	–	.0196	.0163	.0136	.0118	.0102	–	–	2
Valeric	–	.0271	.0220	.0183	.0155	.0127	–	–	3
Salicylic	–	.0320	.0271	.0222	.0181	.0150	–	–	3
Alcohol: Methyl	.00813	.00686	.00591	.00515	.00450	.00396	–	–	4
Ethyl	.01770	.01449	.01192	.00990	.00828	.00698	.00504	–	4
Propyl	.03882	.02917	.02255	.01778	.01403	.01128	.00757	.00526	4
Butyric	.05185	.03872	.02947	.02266	.01780	.01409	.00926	.00633	4
Allyl	.02144	.01703	.01361	.01165	.00911	.00760	.00548	.00407	4
Isopropyl	.04564	.03245	.02369	.01755	.01329	.01026	.00642	–	4
Isobutyl	.08038	.05547	.03906	.02863	.02121	.01609	.00973	.00633	4
Amyl (op.-inac.)	.08532	.06000	.04341	.03206	.02414	.01849	.01147	.00758	4
Aldehyde	.00267	.00244	.00222	–	–	–	–	–	3
Aniline	–	–	.0440	.0319	.0241	.0189	–	–	5
Benzole	.00902	.00759	.00649	.00562	.00492	.00437	.00351	–	4
Bromides: Ethyl	.00478	.00432	.00392	.00357	–	–	–	–	4
Propyl	.00645	.00575	.00517	.00467	.00425	.00388	.00328	–	4
Allyl	.00619	.00552	.00496	.00449	.00410	.00374	.00316	–	4
Ethylene	.02435	.02035	.01716	.01470	.01280	.01124	.00895	.00733	4
Carbon bisulphide	.00429	.00396	.00367	.00342	.00319	–	–	–	4
Carbon dioxide (liq.)	.00099	.00085	.00071	–	–	–	–	–	6
Chlorides: Propyl	.00436	.00390	.00352	.00319	.00291	–	–	–	4
Allyl	.00402	.00358	.00322	.00292	–	–	–	–	4
Ethylene	.01128	.00961	.00833	.00730	.00646	.00576	.00470	–	4
Chloroform	.00700	.00626	.00564	.00511	.00466	.00390	–	–	4
Ether	–	.0026	.0023	.0021	–	–	–	–	1
Ethylbenzole	.00874	.00758	.00666	.00592	.00529	.00477	.00394	.00330	4
Ethylsulphide	.00559	.00496	.00444	.00401	.00363	.00331	.00279	.00237	4
Iodides: Methyl	.00594	.00536	.00487	.00446	.00409	–	–	–1	
Ethyl	.00719	.00645	.00583	.00530	.00484	.00444	.00378	–	
Propyl	.00938	.00827	.00737	.00662	.00598	.00544	.00456	.00387	4
Allyl	.00930	.00819	.00726	.00652	.00588	.00534	.00448	.00381	4
Metaxylol	.00802	.00698	.00615	.00547	.00491	.00444	.00369	.00313	4
Nitrobenzene	–	–	.0203	.0170	.0144	.0124	–	–	1
Paraffines: Pentane	.00283	.00256	.00232	.00212	–	–	–	–	4
Hexane	.00396	.00355	.00320	.00290	.00264	.00241	.00221	–	4
Heptane	.00519	.00460	.00410	.00369	.00334	.00303	.00253	.00214	4
Octane	.00703	.00612	.00538	.00478	.00428	.00386	.00318	.00266	4
Isopentane	.00273	.00246	.00223	.00204	–	–	–	–	4
Isohexane	.00371	.00332	.00300	.00272	.00247	.00226	–	–	4
Isoheptane	.00477	.00423	.00379	.00342	.00309	.00282	.00235	.00200	4
Propyl aldehyde	–	.0047	.0041	.0036	.0033	–	–	–	1
Toluene	.00768	.00668	.00586	.00520	.00466	.00420	.00348	.00292	4

1 Pribram-Handl, Wien. Ber. 78, 1878, 80, 1879, 84, 1881.
2 Gartenmeister, Zeitschr. Phys. Chem. 6, 1890.
3 Rellstab, Diss. Bonn, 1868.
4 Thorpe-Roger, Philos. Trans. 185 A, 1894, 189 A, 1897; Proc. Roy. Soc. 55, 1894, 60, 1896; Jour. Chem. Soc. 71, 1897; Chem. News, 75, 1897.
5 Wijkander, Wied. Beibl. 3, 1879.
6 Warburg-Babo, Wied. Ann. 17, 1882.

* Calculated from the specific viscosities given in Landolt & Börnstein's Phys. Chem. Tab.

For inorganic acids, see Solutions.

VISCOSITY OF SOLUTIONS.

This table is intended to show the effect of change of concentration and change of temperature on the viscosity of solutions of salts in water. The specific viscosity × 100 is given for two or more densities and for several temperatures in the case of each solution. μ stands for specific viscosity, and t for temperature Centigrade.

Salt.	Percentage by weight of salt in solution.	Density.	μ	t	μ	t	μ	t	μ	t	Authority.
$BaCl_2$	7.60	–	77.9	10	44.0	30	35.2	50	–	–	Sprung.
"	15.40	–	86.4	"	56.0	"	39.6	"	–	–	"
"	24.34	–	100.7	"	66.2	"	47.7	"	–	–	"
$Ba(NO_3)_2$	2.98	1.027	62.0	15	51.1	25	42.4	35	34.8	45	Wagner.
"	5.24	1.051	68.1	"	54.2	"	44.1	"	36.9	"	"
$CaCl_2$	15.17	–	110.9	10	71.3	30	50.3	50	–	–	Sprung.
"	31.60	–	272.5	"	177.0	"	124.0	"	–	–	"
"	39.75	–	670.0	"	379.0	"	245.5	"	–	–	"
"	44.09	–	–	–	593.1	"	363.2	"	–	–	"
$Ca(NO_3)_2$	17.55	1.171	93.8	15	74.6	25	60.0	35	49.9	45	Wagner.
"	30.10	1.274	144.1	"	112.7	"	90.7	"	75.1	"	"
"	40.13	1.386	242.6	"	217.1	"	156.5	"	128.1	"	"
$CdCl_2$	11.09	1.109	77.5	15	60.5	25	49.1	35	40.7	45	"
"	16.30	1.181	88.9	"	70.5	"	57.5	"	47.2	"	"
"	24.79	1.320	104.0	"	80.4	"	64.6	"	53.6	"	"
$Cd(NO_3)_2$	7.81	1.074	61.9	15	50.1	25	41.1	35	34.0	45	"
"	15.71	1.159	71.8	"	58.7	"	48.8	"	41.3	"	"
"	22.36	1.241	85.1	"	69.0	"	57.3	"	47.5	"	"
$CdSO_4$	7.14	1.068	78.9	15	61.8	25	49.9	35	41.3	45	"
"	14.66	1.159	96.2	"	72.4	"	58.1	"	48.8	"	"
"	22.01	1.268	120.8	"	91.8	"	73.5	"	60.1	"	"
$CoCl_2$	7.97	1.081	83.0	15	65.1	25	53.6	35	44.9	45	"
"	14.86	1.161	111.6	"	85.1	"	73.7	"	58.8	"	"
"	22.27	1.264	161.6	"	126.6	"	101.6	"	85.6	"	"
$Co(NO_3)_2$	8.28	1.073	74.7	15	57.9	25	48.7	35	39.8	45	"
"	15.96	1.144	87.0	"	69.2	"	55.4	"	44.9	"	"
"	24.53	1.229	110.4	"	88.0	"	71.5	"	59.1	"	"
$CoSO_4$	7.24	1.086	86.7	15	68.7	25	55.0	35	45.1	45	"
"	14.16	1.159	117.8	"	95.5	"	76.0	"	61.7	"	"
"	21.17	1.240	193.6	"	146.2	"	113.0	"	89.9	"	"
$CuCl_2$	12.01	1.104	87.2	15	67.8	25	55.1	35	45.6	45	"
"	21.35	1.215	121.5	"	95.8	"	77.0	"	63.2	"	"
"	33.03	1.331	178.4	"	137.2	"	107.6	"	87.1	"	"
$Cu(NO_3)_2$	18.99	1.177	97.3	15	76.0	25	61.5	35	51.3	45	"
"	26.68	1.264	126.2	"	98.8	"	80.9	"	68.6	"	"
"	46.71	1.536	382.9	"	283.8	"	215.3	"	172.2	"	"
$CuSO_4$	6.79	1.055	79.6	15	61.8	25	49.8	35	41.4	45	"
"	12.57	1.115	98.2	"	74.0	"	59.7	"	52.0	"	"
"	17.49	1.163	124.5	"	96.8	"	75.9	"	61.8	"	"
HCl	8.14	1.037	71.0	15	57.9	25	48.3	35	40.1	45	"
"	16.12	1.084	80.0	"	66.5	"	56.4	"	48.1	"	"
"	23.04	1.114	91.8	"	79.9	"	65.9	"	56.4	"	"
$HgCl_2$	0.23	1.023	–	–	58.5	20	46.8	30	38.3	40	"
"	3.55	1.033	76.75	10	59.2	"	46.6	"	38.3	"	"

VISCOSITY OF SOLUTIONS.

Salt.	Percentage by weight of salt in solution.	Density.	μ	t	μ	t	μ	t	μ	t	Authority.
HNO_3	8.37	1.067	66.4	15	54.8	25	45.4	35	37.6	45	Wagner.
"	12.20	1.116	69.5	"	57.3	"	47.9	"	40.7	"	"
"	28.31	1.178	80.3	"	65.5	"	54.9	"	46.2	"	"
H_2SO_4	7.87	1.065	77.8	15	61.0	25	50.0	35	41.7	45	"
"	15.50	1.130	95.1	"	75.0	"	60.5	"	49.8	"	"
"	23.43	1.200	122.7	"	95.5	"	77.5	"	64.3	"	"
KCl	10.23	–	70.0	10	46.1	30	33.1	50	–	–	Sprung.
"	22.21	–	70.0	"	48.6	"	36.4	"	–	–	"
KBr	14.02	–	67.6	10	44.8	30	32.1	50	–	–	"
"	23.16	–	66.2	"	44.7	"	33.2	"	–	–	"
"	34.64	–	66.6	"	47.0	"	35.7	"	–	–	"
KI	8.42	–	69.5	10	44.0	30	31.3	50	–	–	"
"	17.01	–	65.3	"	42.9	"	31.4	"	–	–	"
"	33.03	–	61.8	"	42.9	"	32.4	"	–	–	"
"	45.98	–	63.0	"	45.2	"	35.3	"	–	–	"
"	54.00	–	68.8	"	48.5	"	37.6	"	–	–	"
$KClO_3$	3.51	–	71.7	10	44.7	30	31.5	50	–	–	"
"	5.69	–	–	"	45.0	"	31.4	"	–	–	"
KNO_3	6.32	–	70.8	10	44.6	30	31.8	50	–	–	"
"	12.19	–	68.7	"	44.8	"	32.3	"	–	–	"
"	17.60	–	68.8	"	46.0	"	33.4	"	–	–	"
K_2SO_4	5.17	–	77.4	10	48.6	30	34.3	50	–	–	"
"	9.77	–	81.0	"	52.0	"	36.9	"	–	–	"
K_2CrO_4	11.93	–	75.8	10	62.5	30	41.0	40	–	–	"
"	19.61	–	85.3	"	68.7	"	47.9	"	–	–	"
"	24.26	1.233	97.8	"	74.5	"	54.5	"	–	–	Slotte.
"	32.78	–	109.5	"	88.9	"	62.6	"	–	–	Sprung.
$K_2Cr_2O_7$	4.71	1.032	72.6	10	55.9	20	45.3	30	37.5	40	Slotte.
"	6.97	1.049	73.1	"	56.4	"	45.5	"	37.7	"	"
LiCl	7.76	–	96.1	10	59.7	30	41.2	50	–	–	Sprung.
"	13.91	–	121.3	"	75.9	"	52.6	"	–	–	"
"	26.93	–	229.4	"	142.1	"	98.0	"	–	–	"
$Mg(NO_3)_2$	18.62	1.102	99.8	15	81.3	25	66.5	35	56.2	45	Wagner.
"	34.19	1.200	213.3	"	164.4	"	132.4	"	109.9	"	"
"	39.77	1.430	317.0	"	250.0	"	191.4	"	158.1	"	"
$MgSO_4$	4.98	–	96.2	10	59.0	30	40.9	50	–	–	Sprung.
"	9.50	–	130.9	"	77.7	"	53.0	"	–	–	"
"	19.32	–	302.2	"	166.4	"	106.0	"	–	–	"
$MgCrO_4$	12.31	1.089	111.3	10	84.8	20	67.4	30	55.0	40	Slotte.
"	21.86	1.164	167.1	"	125.3	"	99.0	"	79.4	"	"
"	27.71	1.217	232.2	"	172.6	"	133.9	"	106.6	"	"
$MnCl_2$	8.01	1.096	92.8	15	71.1	25	57.5	35	48.1	45	Wagner.
"	15.65	1.196	130.9	"	104.2	"	84.0	"	68.7	"	"
"	30.33	1.337	256.3	"	193.2	"	155.0	"	123.7	"	"
"	40.13	1.453	537.3	"	393.4	"	300.4	"	246.5	"	"

VISCOSITY OF SOLUTIONS.

Salt.	Percentage by weight of salt in solution.	Density.	μ	t	μ	t	μ	t	μ	t	Authority.
$Mn(NO_3)_2$	18.31	1.148	96.0	15	76.4	25	64.5	35	55.6	45	Wagner.
"	29.60	1.323	167.5	"	126.0	"	104.6	"	88.6	"	"
"	49.31	1.506	396.8	"	301.1	"	221.0	"	188.8	"	"
$MnSO_4$	11.45	1.147	129.4	15	98.6	25	78.3	35	63.4	45	"
"	18.80	1.251	228.6	"	172.2	"	137.1	"	107.4	"	"
"	22.08	1.306	661.8	"	474.3	"	347.9	"	266.8	"	"
NaCl	7.95	–	82.4	10	52.0	30	31.8	50	–	–	Sprung.
"	14.31	–	94.8	"	60.1	"	36.9	"	–	–	"
"	23.22	–	128.3	"	79.4	"	47.4	"	–	–	"
NaBr	9.77	–	75.6	10	48.7	30	34.4	50	–	–	"
"	18.58	–	82.6	"	53.5	"	38.2	"	–	–	"
"	27.27	–	95.9	"	61.7	"	43.8	"	–	–	"
NaI	8.83	–	73.1	10	46.0	30	32.4	50	–	–	"
"	17.15	–	73.8	"	47.4	"	33.7	"	–	–	"
"	35.69	–	86.0	"	55.7	"	40.6	"	–	–	"
"	55.47	–	157.2	"	96.4	"	66.9	"	–	–	"
$NaClO_3$	11.50	–	78.7	10	50.0	30	35.3	50	–	–	"
"	20.59	–	88.9	"	56.8	"	40.4	"	–	–	"
"	33.54	–	121.0	"	75.7	"	53.0	"	–	–	"
$NaNO_3$	7.25	–	75.6	10	47.9	30	33.8	50	–	–	"
"	12.35	–	81.2	"	51.0	"	36.1	"	–	–	"
"	18.20	–	87.0	"	55.9	"	39.3	"	–	–	"
"	31.55	–	121.2	"	76.2	"	53.4	"	–	–	"
Na_2SO_4	4.98	–	96.2	10	59.0	30	40.9	50	–	–	"
"	9.50	–	130.9	"	77.7	"	53.0	"	–	–	"
"	14.03	–	187.9	"	107.4	"	71.1	"	–	–	"
"	19.32	–	302.2	"	166.4	"	106.0	"	–	–	"
Na_2CrO_4	5.76	1.058	85.8	10	66.6	20	53.4	30	43.8	40	Slotte.
"	10.62	1.112	103.3	"	79.3	"	63.5	"	52.3	"	"
"	14.81	1.164	127.5	"	97.1	"	77.3	"	63.0	"	"
NH_4Cl	3.67	–	71.5	10	45.0	30	31.9	50	–	–	Sprung.
"	8.67	–	69.1	"	45.3	"	32.6	"	–	–	"
"	15.68	–	67.3	"	46.2	"	34.0	"	–	–	"
"	23.37	–	67.4	"	47.7	"	36.1	"	–	–	"
NH_4Br	15.97	–	65.2	10	43.2	30	31.5	50	–	–	"
"	25.33	–	62.6	"	43.3	"	32.2	"	–	–	"
"	36.88	–	62.4	"	44.6	"	34.3	"	–	–	"
NH_4NO_3	5.97	–	69.6	10	44.3	30	31.6	50	–	–	"
"	12.19	–	66.8	"	44.3	"	31.9	"	–	–	"
"	27.08	–	67.0	"	47.7	"	34.9	"	–	–	"
"	37.22	–	71.7	"	51.2	"	38.8	"	–	–	"
"	49.83	–	81.1	"	63.3	"	48.9	"	–	–	"
$(NH_4)_2SO_4$	8.10	–	107.9	10	52.3	30	37.0	50	–	–	"
"	15.94	–	120.2	"	60.4	"	43.2	"	–	–	"
"	25.51	–	148.4	"	74.8	"	54.1	"	–	–	"

VISCOSITY OF SOLUTIONS.

Salt.	Percentage by weight of salt in solution.	Density.	μ	t	μ	t	μ	t	μ	t	Authority.
$(NH_4)_2CrO_4$	10.52	1.063	79.3	10	62.4	20	–	–	42.4	40	Slotte.
"	19.75	1.120	88.2	"	70.0	"	57.8	30	48.4	–	"
"	28.04	1.173	101.1	"	80.7	"	60.8	"	56.4	–	"
$(NH_4)_2Cr_2O_7$	6.85	1.039	72.5	10	56.3	20	45.8	30	38.0	40	"
"	13.00	1.078	72.6	"	57.2	"	46.8	"	39.1	"	"
"	19.93	1.126	77.6	"	58.8	"	48.7	"	40.9	"	"
$NiCl_2$	11.45	1.109	90.4	15	70.0	25	57.5	35	48.2	45	Wagner.
"	22.69	1.226	140.2	"	109.7	"	87.8	"	72.7	"	"
"	30.40	1.337	229.5	"	171.8	"	139.2	"	111.9	"	"
$Ni(NO_3)_2$	16.49	1.136	90.7	15	70.1	25	57.4	35	48.9	45	"
"	30.01	1.278	135.6	"	105.9	"	85.5	"	70.7	"	"
"	40.95	1.388	222.6	"	169.7	"	128.2	"	152.4	"	"
$NiSO_4$	10.62	1.092	94.6	15	73.5	25	60.1	35	49.8	45	"
"	18.19	1.198	154.9	"	119.9	"	99.5	"	75.7	"	"
"	25.35	1.314	298.5	"	224.9	"	173.0	"	152.4	"	"
$Pb(NO_3)_2$	17.93	1.179	74.0	15	59.1	25	48.5	35	40.3	45	"
"	32.22	1.362	91.8	"	72.5	"	59.6	"	50.6	"	"
$Sr(NO_3)_2$	10.29	1.088	69.3	15	56.0	25	45.9	35	39.1	45	"
"	21.19	1.124	87.3	"	69.2	"	57.8	"	48.1	"	"
"	32.61	1.307	116.9	"	93.3	"	76.7	"	62.3	"	"
$ZnCl_2$	15.33	1.146	93.6	15	72.7	25	57.8	35	48.2	45	"
"	23.49	1.229	111.5	"	86.6	"	69.8	"	57.5	"	"
"	33.78	1.343	151.7	"	117.9	"	90.0	"	72.6	"	"
$Zn(NO_3)_2$	15.95	1.115	80.7	15	64.3	25	52.6	35	43.8	45	"
"	30.23	1.229	104.7	"	85.7	"	69.5	"	57.7	"	"
"	44.50	1.437	167.9	"	130.6	"	105.4	"	87.9	"	"
$ZnSO_4$	7.12	1.106	97.1	15	79.3	25	62.7	35	51.5	45	"
"	16.64	1.195	156.0	"	118.6	"	94.2	"	73.5	"	"
"	23.09	1.281	232.8	"	177.4	"	135.2	"	108.1	"	"

TABLE 114.

SPECIFIC VISCOSITY.*

Dissolved salt.	Normal solution.		½ normal.		¼ normal.		⅛ normal.		Authority.
	Density.	Specific viscosity.	Density.	Specific viscosity.	Density.	Specific viscosity.	Density.	Specific viscosity.	
Acids: Cl_2O_3	1.0562	1.012	1.0283	1.003	1.0143	1.000	1.0074	0.999	Reyher.
HCl	1.0177	1.067	1.0092	1.034	1.0045	1.017	1.0025	1.009	"
$HClO_3$	1.0485	1.052	1.0244	1.025	1.0126	1.014	1.0064	1.006	"
HNO_3	1.0332	1.027	1.0168	1.011	1.0086	1.005	1.0044	1.003	"
H_2SO_4	1.0303	1.090	1.0154	1.043	1.0074	1.022	1.0035	1.008	Wagner.
Aluminium sulphate	1.0550	1.406	1.0278	1.178	1.0138	1.082	1.0068	1.038	"
Barium chloride	1.0884	1.123	1.0441	1.057	1.0226	1.026	1.0114	1.013	"
" nitrate	–	–	1.0518	1.044	1.0259	1.021	1.0130	1.008	"
Calcium chloride	1.0446	1.156	1.0218	1.076	1.0105	1.036	1.0050	1.017	"
" nitrate	1.0596	1.117	1.0300	1.053	1.0151	1.022	1.0076	1.008	"
Cadmium chloride	1.0779	1.134	1.0394	1.063	1.0197	1.031	1.0098	1.020	"
" nitrate	1.0954	1.165	1.0479	1.074	1.0249	1.038	1.0119	1.018	"
" sulphate	1.0973	1.348	1.0487	1.157	1.0244	1.078	1.0120	1.033	"
Cobalt chloride	1.0571	1.204	1.0286	1.097	1.0144	1.048	1.0058	1.023	"
" nitrate	1.0728	1.166	1.0369	1.075	1.0184	1.032	1.0094	1.018	"
" sulphate	1.0750	2.354	1.0383	1.160	1.0193	1.077	1.0110	1.040	"
Copper chloride	1.0624	1.205	1.0313	1.098	1.0158	1.047	1.0077	1.027	"
" nitrate	1.0755	1.179	1.0372	1.080	1.0185	1.040	1.0092	1.018	"
" sulphate	1.0790	1.358	1.0402	1.160	1.0205	1.080	1.0103	1.038	"
Lead nitrate	1.1380	1.101	0.0699	1.042	1.0351	1.017	1.0175	1.007	"
Lithium chloride	1.0243	1.142	1.0129	1.066	1.0062	1.031	1.0030	1.012	"
" sulphate	1.0453	1.290	1.0234	1.137	1.0115	1.065	1.0057	1.032	"
Magnesium chloride	1.1375	1.201	1.0188	1.094	1.0091	1.044	1.0043	1.021	"
" nitrate	1.0512	1.171	1.0259	1.082	1.0130	1.040	1.0066	1.020	"
" sulphate	1.0584	1.367	1.0297	1.164	1.0152	1.078	1.0076	1.032	"
Manganese chloride	1.0513	1.209	1.0259	1.098	1.0125	1.048	1.0063	1.023	"
" nitrate	1.0690	1.183	1.0349	1.087	1.0174	1.043	1.0093	1.023	"
" sulphate	1.0728	1.364	1.0365	1.169	1.0179	1.076	1.0087	1.037	"
Nickel chloride	1.0591	1.205	1.0308	1.097	1.0144	1.044	1.0067	1.021	"
" nitrate	1.0755	1.180	1.0381	1.084	1.0192	1.042	1.0096	1.019	"
" sulphate	1.0773	1.361	1.0391	1.161	1.0198	1.075	1.0017	1.032	"
Potassium chloride	1.0466	0.987	1.0235	0.987	1.0117	0.990	1.0059	0.993	"
" chromate	1.0935	1.113	1.0475	1.053	1.0241	1.022	1.0121	1.012	"
" nitrate	1.0605	0.975	1.0305	0.982	1.0161	0.987	1.0075	0.992	"
" sulphate	1.0664	1.105	1.0338	1.049	1.0170	1.021	1.0084	1.008	"
Sodium chloride	1.0401	1.097	1.0208	1.047	1.0107	1.024	1.0056	1.013	Reyher.
" bromide	1.0786	1.064	1.0396	1.030	1.0190	1.015	1.0100	1.008	"
" chlorate	1.0710	1.090	1.0359	1.042	1.0180	1.022	1.0092	1.012	"
" nitrate	1.0554	1.065	1.0281	1.026	1.0141	1.012	1.0071	1.007	"
Silver nitrate	1.1386	1.058	1.0692	1.020	1.0348	1.006	1.0173	1.000	Wagner.
Strontium chloride	1.0676	1.141	1.0336	1.067	1.0171	1.034	1.0084	1.014	"
" nitrate	1.0822	1.115	1.0419	1.049	1.0208	1.024	1.0104	1.011	"
Zinc chloride	1.0590	1.189	1.0302	1.096	1.0152	1.053	1.0077	1.024	"
" nitrate	1.0758	1.164	1.0404	1.086	1.0191	1.039	1.0096	1.019	"
" sulphate	1.0792	1.367	1.0402	1.173	1.0198	1.082	1.0094	1.036	"

* In the case of solutions of salts it has been found (*vide* Arrhennius, Zeits. für Phys. Chem. vol. 1, p. 285) that the specific viscosity can, in many cases, be nearly expressed by the equation $\mu = \mu_1^n$, where μ_1 is the specific viscosity for a normal solution referred to the solvent at the same temperature, and n the number of gramme molecules in the solution under consideration. The same rule may of course be applied to solutions stated in percentages instead of gramme molecules. The table here given has been compiled from the results of Reyher (Zeits. für Phys. Chem. vol. 2, p. 749) and of Wagner (Zeits. für Phys. Chem. vol. 5, p. 31) and illustrates this rule. The numbers are all for 25° C.

VISCOSITY OF GASES AND VAPORS.

The values of μ given in the table are 10^6 times the coefficients of viscosity in C. G. S. units.

Substance.	Temp. °C.	μ.	Reference.	Substance.	Temp. °C.	μ.	Reference.
Acetone	18.0	78.	1	Chloroform	0.0	95.9	1
Air	-21.4	163.9	2	"	17.4	102.9	"
"	0.0	173.3	"	"	61.2	189.0	3
"	15.0	180.7	"	Ether	0.0	68.9	1
"	99.1	220.3	"	"	16.1	73.2	"
"	182.4	255.9	"	"	36.5	79.3	"
"	302.0	299.3	"	Ethyl iodide	72.3	216.0	3
Alcohol: Methyl	66.8	135.	3	Helium	0.0	189.1	5
" Ethyl	78.4	142.	"	"	15.3	196.9	"
" Propyl, norm.	97.4	142.	"	"	66.6	234.8	"
" Isopropyl	82.8	162.	"	"	184.6	269.9	"
" Butyl, norm.	116.9	143.	"	Hydrogen	-20.6	81.9	2
" Isobutyl	108.4	144.	"	"	15.0	88.9	"
" Tert. butyl	82.9	160.	"	"	99.2	105.9	"
Ammonia	0.0	96.	4	"	182.4	121.5	"
"	20.0	108.	"	"	302.0	139.2	"
Argon	0.0	210.4	5	Mercury	270.0	489.*	8
"	14.7	220.8	"	"	300.0	532.*	"
"	17.9	224.1	"	"	330.0	582.*	"
"	99.7	273.3	"	"	360.0	627.*	"
"	183.7	322.1	"	"	390.0	671.*	"
Benzole	19.0	79.	6	Methane	20.0	120.1	4
"	100.0	118.	"	Methyl iodide	44.0	232.	3
Carbon bisulphide	16.9	92.4	1	" chloride	15.0	105.2	2
" dioxide	-20.7	129.4	2	" "	302.0	213.9	"
" "	15.0	145.7	"	Nitrogen	-21.5	156.3	7
" "	99.1	186.1	"	"	10.9	170.7	"
" "	182.4	222.1	"	"	53.5	189.4	"
" "	302.0	268.2	"	Oxygen	15.4	195.7	"
" monoxide	0.0	163.0	4	"	53.5	215.9	"
" "	20.0	184.0	"	Water vapor	0.0	90.4	1
Chlorine	0.0	128.7	"	" "	16.7	96.7	"
"	20.0	147.0	"	" "	100.0	132.0	9

1 Puluj, Wien. Ber. 69, (2), 1874.
2 Breitenbach, Ann. Phys. 5, 1901.
3 Steudel, Wied. Ann. 16, 1882.
4 Graham, Philos. Trans. Lond. 1846, III.
5 Schultze, Ann. Phys. (4), 5, 6, 1901.
6 Schumann, Wied. Ann. 23, 1884.
7 Obermayer, Wien. Ber. 71, (2a), 1875.
8 Koch, Wied. Ann. 14, 1881, 19, 1883.
9 Meyer-Schumann, Wied. Ann. 13, 1881.

* The values here given were calculated from Koch's table (Wied. Ann. vol. 19, p. 869) by the formula $\mu = 489\,[1 + .746\,(t - 270)]$.

TABLE 116.

COEFFICIENT OF VISCOSITY OF GASES.

Temperature Coefficients.

If μ_t = the viscosity at $t°$ C., μ_0 = the vicosity at 0°, α = the coefficient of expansion, β, γ, and n = coefficients independent of t, then

(I) $\mu_t = \mu_0(1+\alpha t)^n$. (Meyer, Obermayer, Puluj, Breitenbach.)

(II) $= \mu_0(1+\beta t)$. (Meyer, Obermayer.)

(III) $= \mu_0(1+\alpha t)^{\frac{1}{2}}(1+\gamma t)^2$. (Schumann.)

(IV) $$= \mu_0 \frac{1+\frac{C}{273}}{1+\frac{C}{T}} \sqrt{1+\frac{t}{273}}.$$ (Sutherland.)

Gas.	$\mu_0 10^7$.	α.	Constants.	Range °C.	Reference.
Air	–	0.003665	$n=0.77$	0–100	1
"	1733.1	.003665	$C=119.4$	–	2
"	1811.	–	$n=0.7675$	15.0–99.7	3
"	2208.	–	$n=0.7544$	99.7–182.9	"
"	–	–	$n=0.754$; $C=111.3$	–	4
Argon	–	–	$n=0.815$; $C=150.2$	15–100	4
"	2208.	–	$n=0.8227$; $C=169.9$	14.7–99.7	3
"	2733.	–	$n=0.8119$	99.7–183.7	3
Benzole	698.4	.004	$\gamma=0.00185$	18.7–100	5
Carbon dioxide	1387.9	–	$C=239.7$	–	6
" "	1497.2	.003701	$\gamma=0.000889$	12.8–100	5
" "	1382.1	.003701	$\beta=0.00348$; $n=0.941$	−21.5–53.5	7
" monoxide	1625.2	.003665	$\beta=0.00269$; $n=0.738$	17.5–53.5	"
Ether	689.	.004158	$n=0.94$	0–36.5	8
Ethylene	961.3	–	$C=225.9$	–	6
"	922.2	.003665	$\beta=0.00350$; $n=0.958$	−21.5–53.5	7
" chloride	889.03	.003900	$\beta=0.00381$; $n=0.9772$	15.6–157.3	"
Helium	–	–	$n=0.681$; $C=72.2$	0–15.0	4
"	1969.	–	$n=0.6852$; $C=80.3$	15.3–99.6	3
"	2348.	–	$n=0.6771$	99.6–184.6	3
Hydrogen	857.4	.00366	$C=71.7$	–	2
"	–	–	$n=0.681$; $C=72.2$	–	4
Mercury	1620.	.003665	$n=1.6$	273–380	10
Nitrogen	1658.6	.003665	$\beta=0.00269$; $n=0.738$	−21.5–53.5	7
Nitrous oxide	1353.3	.003719	$\beta=0.00345$; $n=0.929$	−21.5–100.3	"
Oxygen	–	–	$n=0.782$; $C=128.2$	–	4

1 Holman, Proc. Amer. Acad. 12, 1876; 21, 1885; Philos. Mag. (5) 3, 1877; 21, 1886.
2 Breitenbach, Wied. Ann. 5, 1901.
3 Schultze, Ann. Phys. (4) 5, 1901.
4 Rayleigh, Proc. Roy. Soc. 62, 1897; 66, 1900; 67, 1900.
5 Schumann, Wied. Ann. 23, 1884.
6 Breitenbach, Ann. Phys. 5, 1901.
7 Obermayer, Wien. Ber. 73 (2A), 1876.
8 Puluj, Wien. Ber. 78 (2), 1878.
9 Schultze, Ann. Phys. (4) 6, 1901.
10 Koch, Wied. Ann. 19, 1883.

Compiled from Landolt-Börnstein-Meyerhoffer's Physikalisch-chemische Tabellen.

DIFFUSION OF AN AQUEOUS SOLUTION INTO PURE WATER.

If k is the coefficient of diffusion, dS the amount of the substance which passes in the time dt, at the place x, through q sq. cm. of a diffusion cylinder under the influence of a drop of concentration dc/dx, then

$$dS = -kq \frac{dc}{dx} dt.$$

k depends on the temperature and the concentration. c gives the gram-molecules per litre. The unit of time is a day.

Substance.	c	$t°$	k	Reference
Bromine	0.1	12.	0.8	1
Chlorine	"	12.	1.22	"
Copper sulphate	"	17.	0.39	2
Glycerine	"	10.14	0.357	3
Hydrochloric acid	"	19.2	2.21	2
Iodine	"	12.	(0.5)	1
Nitric acid	"	19.5	2.07	2
Potassium chloride	"	17.5	1.38	2
" hydrate	"	13.5	1.72	2
Silver nitrate	"	12.	0.985	2
Sodium chloride	"	15.0	0.94	2
Urea	"	14.8	0.97	3
Acetic acid	0.2	13.5	0.77	4
Barium chloride	"	8.	0.66	4
Glycerine	"	10.1	3.55	3
Sodium actetate	"	12.	0.67	5
" chloride	"	15.0	0.94	2
Urea	"	14.8	0.969	3
Acetic acid	1.0	12.	0.74	6
Ammonia	"	15.23	1.54	7
Formic acid	"	12.	0.97	7
Glycerine	"	10.14	0.339	3
Hydrochloric acid	"	12.	2.09	6
Magnesium sulphate	"	7.	0.30	4
Potassium bromide	"	10.	1.13	8
" hydrate	"	12.	1.72	6
Sodium chloride	"	15.0	0.94	2
" "	"	14.3	0.964	3
" hydrate	"	12.	1.11	2
" iodide	"	10.	0.80	8
Sugar	"	12.	0.254	6
Sulphuric acid	"	12.	1.12	6
Zinc sulphate	"	14.8	0.236	9
Acetic acid	2.0	12.	0.69	6
Calcium chloride	"	10.	0.68	8
Cadmium sulphate	"	19.04	0.246	9
Hydrochloric acid	"	12.	2.21	6
Sodium iodide	"	10.	0.90	8
Sulphuric acid	"	12.	1.16	6
Zinc acetate	"	18.05	0.210	9
" "	"	0.04	0.120	9
Acetic acid	3.0	12.	0.68	–
Potassium carbonate	"	10.	0.60	8
" hydrate	"	12.	1.89	6
Acetic acid	4.0	12.	0.66	6
Potassium chloride	"	10.	1.27	8

Substance.	c	$t°$	k	Reference
Calcium chloride	0.864	8.5	0.70	4
" "	1.22	9.	0.72	"
" "	0.060	9.	0.64	"
" "	0.047	9.	0.68	"
Copper sulphate	1.95	17.	0.23	2
" "	0.95	17.	0.26	"
" "	0.30	17.	0.33	"
" "	0.005	17.	0.47	"
Glycerine	2/8	10.14	0.354	3
"	6/8	10.14	0.345	"
"	10/8	10.14	0.329	"
"	14/8	10.14	0.300	"
Hydrochloric acid	4.52	11.5	2.93	4
" "	3.16	11.	2.67	"
" "	0.945	11.	2.12	"
" "	0.387	11.	2.02	"
" "	0.250	11.	1.84	"
Magnesium sulphate	2.18	5.5	0.28	4
" "	0.541	5.5	0.32	"
" "	3.23	10.	0.27	"
" "	0.402	10.	0.34	"
Potassium hydrate	0.75	12.	1.72	6
" "	0.49	12.	1.70	"
" "	0.375	12.	1.70	"
" nitrate	3.9	17.6	0.89	2
" "	1.4	17.6	1.10	"
" "	0.3	17.6	1.26	"
" "	0.02	17.6	1.28	"
" sulphate	0.95	19.6	0.79	"
" "	0.28	19.6	0.86	"
" "	0.05	19.6	0.97	"
" "	0.02	19.6	1.01	"
Silver nitrate	3.9	12.	0.535	"
" "	0.9	12.	0.88	"
" "	0.02	12.	1.035	"
Sodium chloride	2/8	14.33	1.013	3
" "	4/8	14.33	0.996	"
" "	6/8	14.33	0.980	2
" "	10/8	14.33	0.948	"
" "	14/8	14.33	0.917	"
Sulphuric acid	9.85	18.	2.36	2
" "	4.85	18.	1.90	"
" "	2.85	18.	1.60	"
" "	0.85	18.	1.34	"
" "	0.35	18.	1.32	"
" "	0.005	18.	1.30	"

1 Euler, Wied. Ann. 63, 1897.
2 Thovert, C. R. 133, 1901; 134, 1902.
3 Heimbrodt, Diss. Leipzig, 1903.
4 Scheffer, Chem. Ber. 15, 1882; 16, 1883; Zeitschr. Phys. Chem. 2, 1888.
5 Kawalki, Wied. Ann. 52, 1894; 59, 1896.
6 Arrhenius, Zeitschr. Phys. Chem. 10, 1892.
7 Abegg, Zeitschr. Phys. Chem. 11, 1893.
8 Schuhmeister, Wien. Ber. 79 (2), 1879.
9 Seitz, Wied. Ann. 64, 1898.

Compiled from Landolt-Börnstein-Meyerhoffer's Physikalisch-chemische Tabellen.

DIFFUSION OF VAPORS.

Coefficients of diffusion of vapors in C. G. S. units. The coefficients are for the temperatures given in the table and a pressure of 76 centimetres of mercury.*

Vapor.	Temp. C. °	k_t for vapor diffusing into hydrogen.	k_t for vapor diffusing into air.	k_t for vapor diffusing into carbon dioxide.
Acids: Formic	0.0	0.5131	0.1315	0.0879
"	65.4	0.7873	0.2035	0.1343
"	84.9	0.8830	0.2244	0.1519
Acetic	0.0	0.4040	0.1061	0.0713
"	65.5	0.6211	0.1578	0.1048
"	98.5	0.7481	0.1965	0.1321
Isovaleric	0.0	0.2118	0.0555	0.0375
"	98.0	0.3934	0.1031	0.0696
Alcohols: Methyl	0.0	0.5001	0.1325	0.0880
"	25.6	0.6015	0.1620	0.1046
"	49.6	0.6738	0.1809	0.1234
Ethyl	0.0	0.3806	0.0994	0.0693
"	40.4	0.5030	0.1372	0.0898
"	66.9	0.5430	0.1475	0.1026
Propyl	0.0	0.3153	0.0803	0.0577
"	66.9	0.4832	0.1237	0.0901
"	83.5	0.5434	0.1379	0.0976
Butyl	0.0	0.2716	0.0681	0.0476
"	99.0	0.5045	0.1265	0.0884
Amyl	0.0	0.2351	0.0589	0.0422
"	99.1	0.4362	0.1094	0.0784
Hexyl	0.0	0.1998	0.0499	0.0351
"	99.0	0.3712	0.0927	0.0651
Benzene	0.0	0.2940	0.0751	0.0527
"	19.9	0.3409	0.0877	0.0609
"	45.0	0.3993	0.1011	0.0715
Carbon disulphide	0.0	0.3690	0.0883	0.0629
" "	19.9	0.4255	0.1015	0.0726
" "	32.8	0.4626	0.1120	0.0789
Esters: Methyl acetate	0.0	0.3277	0.0840	0.0557
" "	20.3	0.3928	0.1013	0.0679
Ethyl "	0.0	0.2373	0.0630	0.0450
" "	46.1	0.3729	0.0970	0.0666
Methyl butyrate	0.0	0.2422	0.0640	0.0438
" "	92.1	0.4308	0.1139	0.0809
Ethyl "	0.0	0.2238	0.0573	0.0406
" "	96.5	0.4112	0.1064	0.0756
" valerate	0.0	0.2050	0.0505	0.0366
" "	97.6	0.3784	0.0932	0.0676
Ether	0.0	0.2960	0.0775	0.0552
"	19.9	0.3410	0.0893	0.0636
Water	0.0	0.6870	0.1980	0.1310
"	49.5	1.0000	0.2827	0.1811
"	92.4	1.1794	0.3451	0.2384

* Taken from Winkelmann's papers (Wied. Ann. vols. 22, 23, and 26). The coefficients for 0° were calculated by Winkelmann on the assumption that the rate of diffusion is proportional to the absolute temperature. According to the investigations of Loschmidt and of Obermeyer the coefficient of diffusion of a gas, or vapor, at 0° C. and a pressure of 76 centimetres of mercury may be calculated from the observed coefficient at another temperature and pressure by the formula $k_0 = k_T \left(\frac{T_0}{T}\right)^n \frac{76}{p}$, where T is temperature absolute and p the pressure of the gas. The exponent n is found to be about 1.75 for the permanent gases and about 2 for condensible gases. The following are examples: Air — CO_2, $n = 1.968$; CO_2 — N_2O, $n = 2.05$; CO_2 — H, $n = 1.742$; CO — O, $n = 1.785$; H — O, $n = 1.755$; O — N, $n = 1.792$. Winkelmann's results, as given in the above table, seem to give about 2 for vapors diffusing into air, hydrogen or carbon dioxide.

DIFFUSION OF GASES, VAPORS, AND METALS.

TABLE 119. — Coefficients of Diffusion for Various Gases and Vapors.*

Gas or Vapor diffusing.	Gas or Vapor diffused into.	Temp. ° C.	Coefficient of Diffusion.	Authority.
Air	Hydrogen	0	0.661	Schulze.
"	Oxygen	0	0.1775	Obermayer.
Carbon dioxide	Air	0	0.1423	Loschmidt.
" "	"	0	0.1360	Waitz.
" "	Carbon monoxide	0	0.1405	Loschmidt.
" "	" "	0	0.1314	Obermayer.
" "	Hydrogen	0	0.5437	"
" "	Methane	0	0.1465	"
" "	Nitrous oxide	0	0.0983	Loschmidt.
" "	Oxygen	0	0.1802	"
Carbon disulphide	Air	0	0.0995	Stefan.
Carbon monoxide	Carbon dioxide	0	0.1314	Obermayer.
" "	Ethylene	0	0.101	"
" "	Hydrogen	0	0.6422	Loschmidt.
" "	Oxygen	0	0.1802	"
" "	"	0	0.1872	Obermayer.
Ether	Air	0	0.0827	Stefan.
"	Hydrogen	0	0.3054	"
Hydrogen	Air	0	0.6340	Obermayer.
"	Carbon dioxide	0	0.5384	"
"	" monoxide	0	0.6488	"
"	Ethane	0	0.4593	"
"	Ethylene	0	0.4863	"
"	Methane	0	0.6254	"
"	Nitrous oxide	0	0.5347	"
"	Oxygen	0	0.6788	"
Nitrogen	"	0	0.1787	"
Oxygen	Carbon dioxide	0	0.1357	"
"	Hydrogen	0	0.7217	Loschmidt.
"	Nitrogen	0	0.1710	Obermayer.
Sulphur dioxide	Hydrogen	0	0.4828	Loschmidt.
Water	Air	8	0.2390	Guglilemo.
"	"	18	0.2475	"
"	Hydrogen	18	0.8710	"

* Compiled for the most part from a similar table in Landolt & Börnstein's Phys. Chem. Tab.

TABLE 119 A. — Diffusion of Metals into Metals.

$\frac{dv}{dt} = k\frac{d^2v}{dx^2}$; where x is the distance in direction of diffusion; v, the degree of concentration of the diffusing metal; t, the time; k, the diffusion constant = the quantity of metal in grammes diffusing through a sq. cm. in a day when unit difference of concentration (gr. per cu. cm.) is maintained between two sides of a layer one cm. thick.

Diffusing Metal.	Dissolving Metal.	Temperature ° C.	k.	Diffusing Metal.	Dissolving Metal.	Temperature ° C.	k.
Gold	Lead	555	3.19	Platinum	Lead	492	1.69
"	"	492	3.00	Lead	Tin	555	3.18
"	"	251	0.03	Rhodium	Lead	550	3.04
"	"	200	0.008	Tin	Mercury	15	1.22*
"	"	165	0.004	Lead	"	15	1.0*
"	"	100	0.00002	Zinc	"	15	1.0*
"	Bismuth	555	4.52	Sodium	"	15	0.45*
"	Tin	555	4.65	Potassium	"	15	0.40*
Silver	"	555	4.14	Gold	"	15	0.72*

From Roberts-Austen, Philosophical Transactions, 1896 A.

* These values are from Guthrie.

SOLUBILITY OF INORGANIC SALTS IN WATER; VARIATION WITH THE TEMPERATURE.

The numbers give the number of grammes of the *anhydrous* salt soluble in 1000 grammes of water at the given temperatures.

Salt.	Temperature Centigrade.										
	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°
$AgNO_3$	1150	1600	2150	2700	3350	4000	4700	5500	6500	7600	9100
$Al_2(SO_4)_3$	313	335	362	404	457	521	591	662	731	808	891
$Al_2K_2(SO_4)_4$	30	–	–	84	–	–	248	–	–	–	1540
$Al_2(NH_4)_2(SO_4)_4$	26	45	66	91	124	159	211	270	352	–	–
B_2O_3	11	15	22	–	40	–	62	–	95	–	157
$BaCl_2$	316	333	357	382	408	436	464	494	524	556	588
$Ba(NO_3)_2$	50	70	92	116	142	171	203	236	270	306	342
$CaCl_2$	595	650	745	1010	1153	–	1368	1417	1470	1527	1590
$CoCl_2$	405	450	500	565	650	935	940	950	960	–	1030
$CsCl$	1614	1747	1865	1973	2080	2185	2290	2395	2500	2601	2705
$CsNO_3$	93	149	230	339	472	644	838	1070	1340	1630	1970
Cs_2SO_4	1671	1731	1787	1841	1899	1949	1999	2050	2103	2149	2203
$Cu(NO_3)_2$	818	–	1250	–	1598	–	1791	–	2078	–	–
$CuSO_4$	149	–	–	255	295	336	390	457	535	627	735
$FeCl_2$	–	–	685	–	–	820	–	–	1040	1050	1060
Fe_2Cl_6	744	819	918	–	–	3151	–	–	5258	–	5357
$FeSO_4$	156	208	264	330	402	486	550	560	506	430	–
$HgCl_2$	43	66	74	84	96	113	139	173	243	371	540
KBr	540	–	650	–	760	–	860	–	955	–	1050
K_2CO_3	1050	–	–	1140	1170	1210	1270	1330	1400	1470	1560
KCl	285	312	343	373	401	429	455	483	510	538	566
$KClO_3$	33	50	71	101	145	197	260	325	396	475	560
K_2CrO_4	589	609	629	650	670	690	710	730	751	771	791
$K_2Cr_2O_7$	50	85	131	–	292	–	505	–	730	–	1020
$KHCO_3$	225	277	332	390	453	522	600	–	–	–	–
KI	1279	1361	1442	1523	1600	1680	1760	1840	1920	2010	2090
KNO_3	133	209	316	458	639	855	1099	1380	1690	2040	2460
KOH	970	1030	1120	1260	1360	1400	1460	1510	1590	1680	1780
K_2PtCl_6	7	9	11	14	18	22	26	32	38	45	52
K_2SO_4	74	92	111	130	148	165	182	198	214	228	241
$LiOH$	127	127	128	129	130	133	138	144	153	–	175
$MgCl_2$	528	535	545	–	575	–	610	–	660	–	730
$MgSO_4$ (7aq)	260	309	356	409	456	–	–	–	–	–	–
" (6aq)	408	422	439	453	–	504	550	596	642	689	738
NH_4Cl	297	333	372	414	458	504	552	602	656	713	773
NH_4HCO_3	119	159	210	270	–	–	–	–	–	–	–
NH_4NO_3	1183	–	–	2418	2970	3540?	4300?	5130?	5800	7400	8710
$(NH_4)_2SO_4$	706	730	754	780	810	844	880	916	953	992	1033
$NaBr$	795	845	903	–	1058	1160	1170	–	1185	–	1205
$Na_2B_4O_7$	–	16	–	39	–	105	200	244	314	408	523
Na_2CO_3 (10aq)	71	126	214	409	–	–	–	–	–	–	–
" (7aq)	204	263	335	435	(1aq)	475	464	458	452	452	452
$NaCl$	356	357	358	360	363	367	371	375	380	385	391
$NaClO_3$	820	890	990	–	1235	–	1470	–	1750	–	2040
Na_2CrO_4	317	502	900	–	960	1050	1150	–	1240	–	1260
$Na_2Cr_2O_7$	1630	1700	1800	1970	2200	2480	2830	3230	3860	–	4330
$NaHCO_3$	69	82	96	111	127	145	164	–	–	–	–
Na_2HPO_4	25	39	93	241	639	–	–	949	–	–	988
NaI	1590	1690	1790	1900	2050	2280	2570	–	2950	–	3020
$NaNO_3$	730	805	880	962	1049	1140	1246	1360	1480	1610	1755

Compiled from Landolt-Börnstein-Meyerhoffer's Physikalisch-chemische Tabellen.

SOLUBILITY OF SALTS AND GASES IN WATER.

TABLE 120 (*continued*).—**Solubility of Inorganic Salts in Water; Variation with the Temperature.**

The numbers give the number of grammes of the *anhydrous* salt soluble in 1000 grammes of water at the given temperatures.

Salt.	Temperature Centigrade.										
	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°
NaOH	420	515	1090	1190	1290	1450	1740	–	3130	–	–
$Na_4P_2O_7$	32	39	62	99	135	174	220	255	300	–	–
Na_2SO_3	141	–	287	–	495	–	–	–	–	–	330
Na_2SO_4 (10aq)	50	90	194	400	}						
" (7aq)	196	305	447	–	} 482	468	455	445	437	429	427
$Na_2S_2O_3$	525	610	700	847	1026	1697	2067	–	2488	2542	2660
$NiCl_2$	–	600	640	680	720	760	810	–	–	–	–
$NiSO_4$	272	–	–	425	–	502	548	594	632	688	776
$PbBr_2$	5	6	8	12	15	20	24	28	33	–	48
$Pb(NO_3)_2$	365	444	523	607	694	787	880	977	1076	1174	1270
RbCl	770	844	911	976	1035	1093	1155	1214	1272	1331	1389
$RbNO_3$	195	330	533	813	1167	1556	2000	2510	3090	3750	5420
Rb_2SO_4	364	426	482	535	585	631	674	714	750	787	818
$SrCl_2$	442	483	539	600	667	744	831	896	924	962	1019
SnI_2	–	–	10	12	14	17	21	25	30	34	40
$Sr(NO_3)_2$	395	549	708	876	913	926	940	956	972	990	1011
$Th(SO_4)_2$ (9aq)	7	10	14	20	30	51	–	–	–	–	–
" (4aq)	–	–	–	–	40	25	16	11	–	–	–
TlCl	2	2	3	5	6	8	10	13	16	20	–
$TlNO_3$	39	62	96	143	209	304	462	695	1110	2000	4140
Tl_2SO_4	27	37	49	62	76	92	109	127	146	165	–
$Yb_2(SO_4)_3$	442	–	–	–	–	–	104	72	69	58	47
$Zn(NO_3)_2$	948	–	–	–	2069	–	–	–	–	–	–
$ZnSO_4$	–	–	–	–	700	768	–	890	860	920	785

TABLE 121.—**Solubility of a Few Organic Salts in Water; Variation with the Temperature.**

Salt.	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°
$H_2(CO_2)_2$	36	53	102	159	228	321	445	635	978	1200	–
$H_2(CH_2.CO_2)_2$	28	45	69	106	162	244	358	511	708	–	1209
Tartaric acid	1150	1260	1390	1560	1760	1950	2180	2440	2730	3070	3430
Racemic "	92	140	206	291	433	595	783	999	1250	1530	1850
$K(HCO_2)$	2900	–	3350	–	3810	–	4550	–	5750	–	7900
$KH(C_4H_4O_4)$	3	4	6	9	13	18	24	32	45	57	69

TABLE 122.—**Solubility of Gases in Water; Variation with the Temperature.**

The table gives the weight in grammes of the gas which will be absorbed in 1000 grammes of water when the partial pressure of the gas plus the vapor pressure of the liquid at the given temperature equals 760 mm.

Gas.	0°	10°	20°	30°	40°	50°	60°	70°	80°
O_2	.0705	.0551	.0443	.0368	.0311	.0263	.0221	.0181	.0135
H_2	.00192	.00174	.00160	.00147	.00138	.00129	.00118	.00102	.00079
N_2	.0293	.0230	.0189	.0161	.0139	.0121	.0105	.0089	.0069
Br_2	431.	248.	148.	94.	62.	40.	28.	18.	11.
Cl_2	–	9.97	7.29	5.72	4.59	3.93	3.30	2.79	2.23
CO_2	3.35	2.32	1.69	1.26	0.97	0.76	0.58	–	–
H_2S	7.10	5.30	3.98	–	–	–	–	–	–
NH_3	987.	689.	535.	422.	–	–	–	–	–
SO_2	228.	162.	113.	78.	54.	–	–	–	–

Compiled from Landolt-Börnstein-Meyerhoffer's Physikalisch-chemische Tabellen.

ABSORPTION OF GASES BY LIQUIDS.*

Temperature Centigrade. t	Absorption Coefficients, a_t, for Gases in Water.						
	Carbon dioxide. CO_2	Carbon monoxide. CO	Hydrogen. H	Nitrogen. N	Nitric oxide. NO	Nitrous oxide. N_2O	Oxygen. O
0	1.797	0.0354	0.02110	0.02399	0.0738	1.048	0.04925
5	1.450	.0315	.02022	.02134	.0646	0.8778	.04335
10	1.185	.0282	.01944	.01918	.0571	0.7377	.03852
15	1.002	.0254	.01875	.01742	.0515	0.6294	.03456
20	0.901	.0232	.01809	.01599	.0471	0.5443	.03137
25	0.772	.0214	.01745	.01481	.0432	–	.02874
30	–	.0200	.01690	.01370	.0400	–	.02646
40	0.506	.0177	.01644	.01195	.0351	–	.02316
50	–	.0161	.01608	.01074	.0315	–	.02080
100	0.244	.0141	.01600	.01011	.0263	–	.01690

Temperature Centigrade. t	Air.	Ammonia. NH_3	Chlorine. Cl	Ethylene. C_2H_4	Methane. CH_4	Hydrogen sulphide. H_2S	Sulphur dioxide. SO_2
0	0.02471	1174.6	3.036	0.2563	0.05473	4.371	79.79
5	.02179	971.5	2.808	.2153	.04889	3.965	67.48
10	.01953	840.2	2.585	.1837	.04367	3.586	56.65
15	.01795	756.0	2.388	.1615	.03903	3.233	47.28
20	.01704	683.1	2.156	.1488	.03499	2.905	39.37
25	–	610.8	1.950	–	.02542	2.604	32.79

Temperature Centigrade. t	Absorption Coefficients, a_t, for Gases in Alcohol, C_2H_5OH.								
	Carbon dioxide. CO_2	Ethylene. C_2H_4	Methane. CH_4	Hydrogen. H	Nitrogen. N	Nitric oxide. NO	Nitrous oxide. N_2O	Hydrogen sulphide. H_2S	Sulphur dioxide. SO_2
0	4.329	3.595	0.5226	0.0692	0.1263	0.3161	4.190	17.89	328.6
5	3.891	3.323	.5086	.0685	.1241	.2998	3.838	14.78	251.7
10	3.514	3.086	.4953	.0679	.1228	.2861	3.525	11.99	190.3
15	3.199	2.882	.4828	.0673	.1214	.2748	3.215	9.54	144.5
20	2.946	2.713	.4710	.0667	.1204	.2659	3.015	7.41	114.5
25	2.756	2.578	.4598	.0662	.1196	.2595	2.819	5.62	99.8

* This table contains the volumes of different gases, supposed measured at 0° C. and 76 centimetres' pressure, which unit volume of the liquid named will absorb at atmospheric pressure and the temperature stated in the first column. The numbers tabulated are commonly called the absorption coefficients for the gases in water, or in alcohol, at the temperature t and under one atmosphere of pressure. The table has been compiled from data published by Bohr & Bock, Bunsen, Carius, Dittmar, Hamberg, Henrick, Pagliano & Emo, Raoult, Schönfeld, Setschenow, and Winkler. The numbers are in many cases averages from several of these authorities.

NOTE. — The effect of increase of pressure is generally to increase the absorption coefficient. The following is approximately the magnitude of the effect in the case of ammonia in alcohol at a temperature of 23° C.:

P	= 45 cms.	50 cms.	55 cms.	60 cms.	65 cms.
a_{23}	= 69	74	79	84	88

According to Setschenow the effect of varying the pressure from 45 to 85 centimetres in the case of carbonic acid in water is very small.

CAPILLARITY.—SURFACE TENSION OF LIQUIDS.*

TABLE 124.—Water and Alcohol in Contact with Air.

Temp. C.	Surface tension in dynes per centimetre.		Temp. C.	Surface tension in dynes per centimetre.		Temp. C.	Surface tension in dynes per centimetre.
	Water.	Ethyl alcohol.		Water.	Ethyl alcohol.		Water.
0°	75.6	23.5	40°	70.0	20.0	80°	64.3
5	74.9	23.1	45	69.3	19.5	85	63.6
10	74.2	22.6	50	68.6	19.1	90	62.9
15	73.5	22.2	55	67.8	18.6	95	62.2
20	72.8	21.7	60	67.1	18.2	100	61.5
25	72.1	21.3	65	66.4	17.8	–	–
30	71.4	20.8	70	65.7	17.3	–	–
35	70.7	20.4	75	65.0	16.9	–	–

TABLE 125.—Miscellaneous Liquids in Contact with Air.

Liquid.	Temp. C.°	Surface tension in dynes per centimetre.	Authority.
Aceton	16.8	23.3	Ramsay-Shields.
Acetic acid . . .	17.0	30.2	Average of various.
Amyl alcohol . .	15.0	24.8	"
Benzene	15.0	28.8	"
Butyric acid . .	15.0	28.7	"
Carbon disulphide	20.0	30.5	Quincke.
Chloroform . .	20.0	28.3	Average of various.
Ether	20.0	18.4	"
Glycerine . . .	17.0	63.14	Hall.
Hexane	0.0	21.2	Schiff.
"	68.0	14.2	"
Mercury	18.0	520.0	Average of various.
Methyl alcohol .	15.0	24.7	"
Olive oil	20.0	34.7	"
Petroleum . . .	20.0	25.9	Magie.
Propyl alcohol .	5.8	25.9	Schiff.
" " . .	97.1	18.0	"
Toluol	15.0	29.1	"
"	109.8	18.9	"
Turpentine . . .	21.0	28.5	Average of various.

TABLE 126.—Solutions of Salts in Water.†

Salt in solution.	Density.	Temp. C.°	Tension in dynes per cm.
$BaCl_2$	1.2820	15–16	81.8
"	1.0497	15–16	77.5
$CaCl_2$	1.3511	19	95.0
"	1.2773	19	90.2
HCl	1.1190	20	73.6
"	1.0887	20	74.5
"	1.0242	20	75.3
KCl	1.1699	15–16	82.8
"	1.1011	15–16	80.1
"	1.0463	15–16	78.2
$MgCl_2$	1.2338	15–16	90.1
"	1.1694	15–16	85.2
"	1.0362	15–16	78.0
NaCl	1.1932	20	85.8
"	1.1074	20	80.5
"	1.0360	20	77.6
NH_4Cl	1.0758	16	84.3
"	1.0535	16	81.7
"	1.0281	16	78.8
$SrCl_2$	1.3114	15–16	85.6
"	1.1204	15–16	79.4
"	1.0567	15–16	77.8
K_2CO_3	1.3575	15–16	90.9
"	1.1576	15–16	81.8
"	1.0400	15–16	77.5
Na_2CO_3	1.1329	14–15	79.3
"	1.0605	14–15	77.8
"	1.0283	14–15	77.2
KNO_3	1.1263	14	78.9
"	1.0466	14	77.6
$NaNO_3$	1.3022	12	83.5
"	1.1311	12	80.0
$CuSO_4$	1.1775	15–16	78.6
"	1.0276	15–16	77.0
H_2SO_4	1.8278	15	63.0?
"	1.4453	15	79.7
"	1.2636	15	79.7
K_2SO_4	1.0744	15–16	78.0
"	1.0360	15–16	77.4
$MgSO_4$	1.2744	15–16	83.2
"	1.0680	15–16	77.8
Mn_2SO_4	1.1119	15–16	79.1
"	1.0329	15–16	77.3
$ZnSO_4$	1.3981	15–16	83.3
"	1.2830	15–16	80.7
"	1.1039	15–16	77.8

* This determination of the capillary constants of liquids has been the subject of many careful experiments, but the results of the different experimenters, and even of the same observer when the method of measurement is changed, do not agree well together. The values here quoted can only be taken as approximations to the actual values for the liquids in a state of purity in contact with pure air. In the case of water the values given by Lord Rayleigh from the wave length of ripples (Phil. Mag. 1890) and by Hall from direct measurement of the tension of a flat film (Phil. Mag. 1893) have been preferred, and the temperature correction has been taken as 0.141 dyne per degree centigrade. The values for alcohol were derived from the experiments of Hall above referred to and the experiments on the effect of temperature made by Timberg (Wied. Ann. vol. 30).

The authority for a few of the other values given is quoted, but they are for the most part average values derived from a large number of results published by different experimenters.

† From Volkmann (Wied. Ann. vol. 17, p. 353).

TENSION OF LIQUIDS.

TABLE 127. — Surface Tension of Liquids.*

Liquid.	Specific gravity.	Surface tension in dynes per centimetre of liquid in contact with —		
		Air.	Water.	Mercury.
Water	1.0	75.0	0.0	(392)
Mercury	13.543	513.0	392.0	0
Bisulphide of carbon	1.2687	30.5	41.7	(387)
Chloroform	1.4878	(31.8)	26.8	(415)
Ethyl alcohol	0.7906	(24.1)	–	364
Olive oil	0.9136	34.6	18.6	317
Turpentine	0.8867	28.8	11.5	241
Petroleum	9.7977	29.7	(28.9)	271
Hydrochloric acid	1.10	(72.9)	–	(392)
Hyposulphite of soda solution	1.1248	69.9	–	429

TABLE 128. — Surface Tension of Liquids at Solidifying Point.†

Substance.	Temperature of solidification. Cent.°	Surface tension in dynes per centimetre.	Substance.	Temperature of solidification. Cent.°	Surface tension in dynes per centimetre.
Platinum	2000	1691	Antimony	432	249
Gold	1200	1003	Borax	1000	216
Zinc	360	877	Carbonate of soda	1000	210
Tin	230	599	Chloride of sodium	–	116
Mercury	—40	588	Water	0	87.9‡
Lead	330	457	Selenium	217	71.8
Silver	1000	427	Sulphur	111	42.1
Bismuth	265	1390	Phosphorus	43	42.0
Potassium	58	371	Wax	68	34.1
Sodium	90	258			

TABLE 129. — Tension of Soap Films.

Elaborate measurements of the thickness of soap films have been made by Reinold and Rucker.‖ They find that a film of oleate of soda solution containing 1 of soap to 70 of water, and having 3 per cent of KNO_3 added to increase electrical conductivity, breaks at a thickness varying between 7.2 and 14.5 micro-millimetres, the average being 12.1 micro-millimetres. The film becomes black and apparently of nearly uniform thickness round the point where fracture begins. Outside the black patch there is the usual display of colors, and the thickness at these parts may be estimated from the colors of thin plates and the refractive index of the solution (*vide* Newton's rings, Table 146).

When the percentage of KNO_3 is diminished, the thickness of the black patch increases. For example, KNO_3 = 3 1 0.5 0.0

Thickness = 12.4 13.5 14.5 22.1 micro-mm.

A similar variation was found in the other soaps.

It was also found that diminishing the proportion of soap in the solution, there being no KNO_3 dissolved, increased the thickness of the film.

1 part soap to 30 of water gave thickness 21.6 micro-mm.
1 part soap to 40 of water gave thickness 22.1 micro-mm.
1 part soap to 60 of water gave thickness 27.7 micro-mm.
1 part soap to 80 of water gave thickness 29.3 micro-mm.

* This table of tensions at the surface separating the liquid named in the first column and air, water or mercury as stated at the head of the last three columns, is from Quincke's experiments (Pogg. Ann. vol. 130, and Phil. Mag. 1871). The numbers given are the equivalent in dynes per centimetre of those obtained by Worthington from Quincke's results (Phil. Mag. vol. 20, 1885) with the exception of those in brackets, which were not corrected by Worthington; they are probably somewhat too high, for the reason stated by Worthington. The temperature was about 20° C.

† Quincke, "Pogg. Ann." vol. 135, p. 661.

‡ It will be observed that the value here given on the authority of Quincke is much higher than his subsequent measurements, as quoted above, give.

‖ "Proc. Roy. Soc." 1877, and "Phil. Trans. Roy. Soc." 1881, 1883, and 1893.

NOTE. — Quincke points out that substances may be divided into groups in each of which the ratio of the surface tension to the density is nearly constant. Thus, if this ratio for mercury be taken as unit, the ratio for the bromides and iodides is about a half: that of the nitrates, chlorides, sugars, and fats, as well as the metals, lead, bismuth, and antimony, about 1; that of water, the carbonates, sulphates, and probably phosphates, and the metals platinum, gold, silver, cadmium, tin, and copper, 2; that of zinc, iron, and palladium, 3; and that of sodium, 6.

VAPOR PRESSURES.

The vapor pressures here tabulated have been taken, with one exception, from Regnault's results. The vapor pressure of Pictet's fluid is given on his own authority. The pressures are in centimetres of mercury.

Temperature Cent.	Acetone. C_3H_6O	Benzol. C_6H_6	Carbon bisulphide. CS_2	Carbon tetrachloride. CCl_4	Chloroform. $CHCl_3$	Ethyl alcohol. C_2H_6O	Ethyl ether. $C_4H_{10}O$	Ethyl bromide. C_2H_5Br	Methyl alcohol. CH_4O	Turpentine. $C_{10}H_6$
—25°	–	–	–	–	–	–	–	4.41	.41	–
—20	–	.58	4.73	.98	–	.33	6.89	5.92	.63	–
—15	–	.88	6.16	1.35	–	.51	8.93	7.81	.93	–
—10	–	1.29	7.94	1.85	–	.65	11.47	10.15	1.35	–
—5	–	1.83	10.13	2.48	–	.91	14.61	13.06	1.92	–
0	–	2.53	12.79	3.29	5.97	1.27	18.44	16.56	2.68	.21
5	–	3.42	16.00	4.32	–	1.76	23.09	20.72	3.69	–
10	–	4.52	19.85	5.60	10.05	2.42	28.68	25.74	5.01	.29
15	–	5.89	24.41	7.17	–	3.30	35.36	31.69	6.71	–
20	17.96	7.56	29.80	9.10	16.05	4.45	43.28	38.70	8.87	.44
25	22.63	9.59	36.11	11.43	20.02	5.94	52.59	46.91	11.60	–
30	28.10	12.02	43.46	14.23	24.75	7.85	63.48	56.45	15.00	.69
35	34.52	14.93	51.97	17.55	30.35	10.29	76.12	67.49	19.20	–
40	42.01	18.36	61.75	21.48	36.93	13.37	90.70	80.19	24.35	1.08
45	50.75	22.41	72.95	26.08	44.60	17.22	107.42	94.73	30.61	–
50	62.29	27.14	85.71	31.44	53.50	21.99	126.48	111.28	38.17	1.70
55	72.59	32.64	100.16	37.63	63.77	27.86	148.11	130.03	47.22	–
60	86.05	39.01	116.45	44.74	75.54	35.02	172.50	151.19	57.99	2.65
65	101.43	46.34	134.75	52.87	88.97	43.69	199.89	174.95	70.73	–
70	118.94	54.74	155.21	62.11	104.21	54.11	230.49	201.51	85.71	4.06
75	138.76	64.32	177.99	72.57	121.42	66.55	264.54	231.07	103.21	–
80	161.10	75.19	203.25	84.33	140.76	81.29	302.28	263.86	123.85	6.13
85	186.18	87.46	231.17	97.51	162.41	98.64	343.95	300.06	147.09	–
90	214.17	101.27	261.91	112.23	186.52	118.93	389.83	339.89	174.17	9.06
95	245.28	116.75	296.63	128.69	213.28	142.51	440.18	383.55	205.17	–
100	279.73	134.01	332.51	146.71	242.85	169.75	495.33	431.23	240.51	13.11
105	317.70	153.18	372.72	166.72	275.40	201.04	555.62	483.12	280.63	–
110	359.40	174.44	416.41	188.74	311.10	236.76	621.46	539.40	325.96	18.60
115	405.00	197.82	463.74	212.91	350.10	277.34	693.33	600.24	376.98	–
120	454.69	223.54	514.88	239.37	392.57	323.17	771.92	665.80	434.18	25.70
125	508.62	251.71	569.97	268.24	438.66	374.69	–	736.22	498.05	–
130	566.97	282.43	629.16	299.69	488.51	432.30	–	811.65	569.13	34.90
135	629.87	315.85	692.59	333.86	542.25	496.42	–	892.19	647.93	–
140	697.44	352.07	760.40	370.90	600.02	567.46	–	977.96	733.71	46.40
145	–	391.21	832.69	411.00	661.92	645.80	–	–	830.89	–
150	–	433.37	909.59	454.31	728.06	731.84	–	–	936.13	60.50
155	–	478.65	–	501.02	798.53	825.92	–	–	–	68.60
160	–	527.14	–	551.31	873.42	–	–	–	–	77.50
165	–	568.30	–	605.38	952.78	–	–	–	–	–
170	–	634.07	–	663.44	–	–	–	–	–	–

VAPOR PRESSURES.

Temperature, Centigrade.	Ammonia. NH_3	Carbon dioxide. CO_2	Ethyl chloride. C_2H_5Cl	Ethyl iodide. C_2H_5I	Methyl chloride. CH_3Cl	Methylic ether. C_2H_6O	Nitrous oxide. N_2O	Pictet's fluid. $64SO_2+44CO_2$ by weight	Sulphur dioxide. SO_2	Hydrogen sulphide. H_2S
—30°	86.61	–	11.02	–	57.90	57.65	–	58.52	28.75	–
—25	110.43	1300.70	14.50	–	71.78	71.61	1569.49	67.64	37.38	374.93
—20	139.21	1514.24	18.75	–	88.32	88.20	1758.66	74.48	47.95	443.85
—15	173.65	1758.25	23.96	–	107.92	107.77	1968.43	89.68	60.79	519.65
—10	214.46	2034.02	30.21	–	130.96	130.66	2200.80	101.84	76.25	608.46
—5	264.42	2344.13	37.67	–	157.87	157.25	2457.92	121.60	94.69	706.60
0	318.33	2690.66	46.52	4.19	189.10	187.90	2742.10	139.08	116.51	820.63
5	383.03	3075.38	56.93	5.41	225.11	222.90	3055.86	167.20	142.11	949.08
10	457.40	3499.86	61.11	6.92	266.38	262.90	3401.91	193.80	171.95	1089.63
15	543.34	3964.69	83.26	8.76	313.41	307.98	3783.17	226.48	206.49	1244.79
20	638.78	4471.66	99.62	11.00	366.69	358.60	4202.79	258.40	246.20	1415.15
25	747.70	5020.73	118.42	13.69	426.74	415.10	4664.14	297.92	291.60	1601.24
30	870.10	5611.90	139.90	16.91	494.05	477.80	5170.85	338.20	343.18	1803.53
35	1007.02	6244.73	164.32	20.71	569.11	–	6335.98	383.80	401.48	2002.43
40	1159.53	6918.44	191.96	25.17	–	–	–	434.72	467.02	2258.25
45	1328.73	7631.46	223.07	30.38	–	–	–	478.80	540.35	2495.43
50	1515.83	–	257.94	36.40	–	–	–	521.36	622.00	2781.48
55	1721.98	–	266.84	43.32	–	–	–	–	712.50	3069.07
60	1948.21	–	340.05	51.22	–	–	–	–	812.38	3374.02
65	2196.51	–	387.85	–	–	–	–	–	922.14	3696.15
70	2467.55	–	440.50	–	–	–	–	–	–	4035.32
75	2763.00	–	498.27	–	–	–	–	–	–	–
80	3084.31	–	561.41	–	–	–	–	–	–	–
85	3433.09	–	630.16	–	–	–	–	–	–	–
90	3810.92	–	704.75	–	–	–	–	–	–	–
95	4219.57	–	785.39	–	–	–	–	–	–	–
100	4660.82	–	872.28	–	–	–	–	–	–	–

VAPOR PRESSURE.

TABLE 131. — Vapor Pressure of Ethyl Alcohol.*

Temp. C.	0°	1°	2°	3°	4°	5°	6°	7°	8°	9°
	Vapor pressure in millimetres of mercury at o° C.									
0°	12.24	13.18	14.15	15.16	16.21	17.31	18.46	19.68	20.98	22.34
10	23.78	25.31	27.94	28.67	30.50	32.44	34.49	36.67	38.97	41.40
20	44.00	46.66	49.47	52.44	55.56	58.86	62.33	65.97	69.80	73.83
30	78.06	82.50	87.17	92.07	97.21	102.60	108.24	114.15	120.35	126.86
40	133.70	140.75	148.10	155.80	163.80	172.20	181.00	190.10	199.65	209.60
50	220.00	230.80	242.50	253.80	265.90	278.60	291.85	305.65	319.95	334.85
60	350.30	366.40	383.10	400.40	418.35	437.00	456.35	476.45	497.25	518.85
70	541.20	564.35	588.35	613.20	638.95	665.55	693.10	721.55	751.00	781.45

From the formula $\log p = a + b\alpha^t + c\beta^t$ Ramsay and Young obtain the following numbers.†

Temp. C.	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°
	Vapor pressure in millimetres of mercury at o° C.									
0°	12.24	23.73	43.97	78.11	133.42	219.82	350.21	540.91	811.81	1186.5
100	1692.3	2359.8	3223.0	4318.7	5686.6	7368.7	9409.9	11858.	14764.	18185.
200	22182.	26825.	32196.	38389.	45519.					

TABLE 132. — Vapor Pressure of Methyl Alcohol.‡

Temp. C.	0°	1°	2°	3°	4°	5°	6°	7°	8°	9°
	Vapor pressure in millimetres of mercury at o° C.									
0°	29.97	31.6	33.6	35.6	37.8	40.2	42.6	45.2	47.9	50.8
10	53.8	57.0	60.3	63.8	67.5	71.4	75.5	79.8	84.3	89.0
20	94.0	99.2	104.7	110.4	116.5	122.7	129.3	136.2	143.4	151.0
30	158.9	167.1	175.7	184.7	194.1	203.9	214.1	224.7	235.8	247.4
40	259.4	271.9	285.0	298.5	312.6	327.3	342.5	358.3	374.7	391.7
50	409.4	427.7	446.6	466.3	486.6	507.7	529.5	552.0	575.3	599.4
60	624.3	650.0	676.5	703.8	732.0	761.1	791.1	822.0	–	–

* This table has been compiled from results published by Ramsay and Young (Jour. Chem. Soc. vol. 47, and Phil. Trans. Roy. Soc., 1886).

† In this formula $a = 5.0720301$; $\log b = \bar{2}.6406131$; $\log c = 0.6050854$; $\log \alpha = 0.003377538$; $\log \beta = \bar{1}.9968424$ (c is negative).

‡ Taken from a paper by Dittmar and Fawsitt (Trans. Roy. Soc. Edin. vol. 33).

TABLE 133.

VAPOR PRESSURE.*

Carbon Disulphide, Chlorobenzene, Bromobenzene, and Aniline.

Temp.	0°	1°	2°	3°	4°	5°	6°	7°	8°	9°
					(a) CARBON DISULPHIDE.					
0°	127.90	133.85	140.05	146.45	153.10	160.00	167.15	174.60	182.25	190.20
10	198.45	207.00	215.80	224.95	234.40	244.15	254.25	264.65	275.40	286.55
20	298.05	309.90	322.10	334.70	347.70	361.10	374.95	389.20	403.90	419.00
30	434.60	450.65	467.15	484.15	501.65	519.65	538.15	557.15	576.75	596.85
40	617.50	638.70	660.50	682.90	705.90	729.50	753.75	778.60	804.10	830.25
					(b) CHLOROBENZENE.					
20°	8.65	9.14	9.66	10.21	10.79	11.40	12.04	12.71	13.42	14.17
30	14.95	15.77	16.63	17.53	18.47	19.45	20.48	21.56	22.69	23.87
40	25.10	26.38	27.72	29.12	30.58	32.10	33.69	35.35	37.08	38.88
50	40.75	42.69	44.72	46.84	49.05	51.35	53.74	56.22	58.79	61.45
60	64.20	67.06	70.03	73.11	76.30	79.60	83.02	86.56	90.22	94.00
70	97.90	101.95	106.10	110.41	114.85	119.45	124.20	129.10	134.15	139.40
80	144.80	150.30	156.05	161.95	168.00	174.25	181.70	187.30	194.10	201.15
90	208.35	215.80	223.45	231.30	239.35	247.70	256.20	265.00	274.00	283.25
100	292.75	302.50	312.50	322.80	333.35	344.15	355.25	366.65	378.30	390.25
110	402.55	415.10	427.95	441.15	454.65	468.50	482.65	497.20	512.05	527.25
120	542.80	558.70	575.05	591.70	608.75	626.15	643.95	662.15	680.75	699.65
130	718.95	738.65	758.80	–	–	–	–	–	–	–
					(c) BROMOBENZENE.					
40°	–	–	–	–	–	12.40	13.06	13.75	14.47	15.22
50	16.00	16.82	17.68	18.58	19.52	20.50	21.52	22.59	23.71	24.88
60	26.10	27.36	28.68	30.06	31.50	33.00	34.56	36.18	37.86	39.60
70	41.40	43.28	45.24	47.28	49.40	51.60	53.88	56.25	58.71	61.26
80	63.90	66.64	69.48	72.42	75.46	78.60	81.84	85.20	88.68	92.28
90	96.00	99.84	103.80	107.88	112.08	116.40	120.86	125.46	130.20	135.08
100	140.10	145.26	150.57	156.03	161.64	167.40	173.32	179.41	185.67	192.10
110	198.70	205.48	212.44	219.58	226.90	234.40	242.10	250.00	258.10	266.40
120	274.90	283.65	292.60	301.75	311.15	320.80	330.70	340.80	351.15	361.80
130	372.65	383.75	395.10	406.70	418.60	430.75	443.20	455.90	468.90	482.20
140	495.80	509.70	523.90	538.40	553.20	568.35	583.85	599.65	615.75	632.25
150	649.05	666.25	683.80	701.65	719.95	738.55	757.55	776.95	796.70	816.90
					(d) ANILINE.					
80°	18.80	19.78	20.79	21.83	22.90	24.00	25.14	26.32	27.54	28.80
90	30.10	31.44	32.83	34.27	35.76	37.30	38.90	40.56	42.28	44.06
100	45.90	47.80	49.78	51.84	53.98	56.20	58.50	60.88	63.34	65.88
110	68.50	71.22	74.04	76.96	79.98	83.10	86.32	89.66	93.12	96.70
120	100.40	104.22	108.17	112.25	116.46	120.80	125.28	129.91	134.69	139.62
130	144.70	149.94	155.34	160.90	166.62	172.50	178.56	184.80	191.22	197.82
140	204.60	211.58	218.76	226.14	233.72	241.50	249.50	257.72	266.16	274.82
150	283.70	292.80	302.15	311.75	321.60	331.70	342.05	352.65	363.50	374.60
160	386.00	397.65	409.60	421.80	434.30	447.10	460.20	473.60	487.25	501.25
170	515.60	530.20	545.20	560.45	576.10	592.05	608.35	625.05	642.05	659.45
180	677.15	695.30	713.75	732.65	751.90	771.50	–	–	–	–

* These tables of vapor pressures are quoted from results published by Ramsay and Young (Jour. Chem. Soc. vol. 47). The tables are intended to give a series suitable for hot-jacket purposes.

VAPOR PRESSURE.

Methyl Salicylate, Bromonaphthaline, and Mercury.

Temp. C.	0°	1°	2°	3°	4°	5°	6°	7°	8°	9°
					(e) METHYL SALICYLATE.					
70°	2.40	2.58	2.77	2.97	3.18	3.40	3.62	3.85	4.09	4.34
80	4.60	4.87	5.15	5.44	5.74	6.05	6.37	6.70	7.05	7.42
90	7.80	8.20	8.62	9.06	9.52	9.95	10.44	10.95	11.48	12.03
100	12.60	13.20	13.82	14.47	15.15	15.85	16.58	17.34	18.13	18.95
110	19.80	20.68	21.60	22.55	23.53	24.55	25.61	26.71	27.85	29.03
120	30.25	31.52	32.84	34.21	35.63	37.10	38.67	40.24	41.84	43.54
130	45.30	47.12	49.01	50.96	52.97	55.05	57.20	59.43	61.73	64.10
140	66.55	69.08	71.69	74.38	77.15	80.00	82.94	85.97	89.09	92.30
150	95.60	99.00	102.50	106.10	109.80	113.60	117.51	121.53	125.66	129.90
160	134.25	138.72	143.31	148.03	152.88	157.85	162.95	168.19	173.56	179.06
170	184.70	190.48	196.41	202.49	208.72	215.10	221.65	228.30	235.15	242.15
180	249.35	256.70	264.20	271.90	279.75	287.80	296.00	304.48	313.05	321.85
190	330.85	340.05	349.45	359.05	368.85	378.90	389.15	399.60	410.30	421.20
200	432.35	443.75	455.35	467.25	479.35	491.70	504.35	517.25	530.40	543.80
210	557.50	571.45	585.70	600.25	615.05	630.15	645.55	661.25	677.25	693.60
220	710.10	727.05	744.35	761.90	779.85	798.10				
					(f) BROMONAPHTHALINE.					
110°	3.60	3.74	3.89	4.05	4.22	4.40	4.59	4.79	5.00	5.22
120	5.45	5.70	5.96	6.23	6.51	6.80	7.10	7.42	7.76	8.12
130	8.50	8.89	9.29	9.71	10.15	10.60	11.07	11.56	12.07	12.60
140	13.15	13.72	14.31	14.92	15.55	16.20	16.87	17.56	18.28	19.03
150	19.80	20.59	21.41	22.25	23.11	24.00	24.92	25.86	26.83	27.83
160	28.85	29.90	30.98	32.09	33.23	34.40	35.60	36.83	38.10	39.41
170	40.75	42.12	43.53	44.99	46.50	48.05	49.64	51.28	52.96	54.68
180	56.45	58.27	60.14	62.04	64.06	66.10	68.19	70.34	72.55	74.82
190	77.15	79.54	81.99	84.51	87.10	89.75	92.47	95.26	98.12	101.05
200	104.05	107.12	110.27	113.50	116.81	120.20	123.67	127.22	130.86	134.59
210	138.40	142.30	146.29	150.38	154.57	158.85	163.25	167.70	172.30	176.95
220	181.75	186.65	191.65	196.75	202.00	207.35	212.80	218.40	224.15	230.00
230	235.95	242.05	248.30	254.65	261.20	267.85	274.65	281.60	288.70	295.95
240	303.35	310.90	318.65	326.50	334.55	342.75	351.10	359.65	368.40	377.30
250	386.35	395.60	405.05	414.65	424.45	434.45	444.65	455.00	465.60	476.35
260	487.35	498.55	509.90	521.50	533.35	545.35	557.60	570.05	582.70	595.60
270	608.75	622.10	635.70	649.50	663.55	677.85	692.40	707.15	722.15	737.45
					(g) MERCURY.					
270°	123.92	126.97	130.08	133.26	136.50	139.81	143.18	146.61	150.12	153.70
280	157.35	161.07	164.86	168.73	172.67	176.79	180.88	185.05	189.30	193.63
290	198.04	202.53	207.10	211.76	216.50	221.33	226.25	231.25	236.34	241.53
300	246.81	252.18	257.65	263.21	268.87	274.63	280.48	286.43	292.49	298.66
310	304.93	311.30	317.78	324.37	331.08	337.89	344.81	351.85	359.00	366.28
320	373.67	381.18	388.81	396.56	404.43	412.44	420.58	428.83	437.22	445.75
330	454.41	463.20	472.12	481.19	490.40	499.74	509.22	518.85	528.63	538.56
340	548.64	558.87	569.25	579.78	590.48	601.33	612.34	623.51	634.85	646.36
350	658.03	669.86	681.86	694.04	706.40	718.94	731.65	744.54	757.61	770.87
360	784.31									

TABLE 134.

VAPOR PRESSURE OF SOLUTIONS OF SALTS IN WATER.*

The first column gives the chemical formula of the salt. The headings of the other columns give the number of gramme-molecules of the salt in a litre of water. The numbers in these columns give the lowering of the vapor pressure produced by the salt at the temperature of boiling water under 76 centimetres barometric pressure.

Substance.	0.5	1.0	2.0	3.0	4.0	5.0	6.0	8.0	10.0
$Al_2(SO_4)_3$	12.8	36.5							
$AlCl_3$	22.5	61.0	179.0	318.0					
$Ba(SO_3)_2$	6.6	15.4	34.4						
$Ba(OH)_2$	12.3	22.5	39.0						
$Ba(NO_3)_2$	13.5	27.0							
$Ba(ClO_3)_2$	15.8	33.3	70.5	108.2					
$BaCl_2$	16.4	36.7	77.6						
$BaBr_2$	16.8	38.8	91.4	150.0	204.7				
$Ca(SO_3)_2$	9.9	23.0	56.0	106.0					
$Ca(NO_3)_2$	16.4	34.8	74.6	139.3	161.7	205.4			
$CaCl_2$	17.0	39.8	95.3	166.6	241.5	319.5			
$CaBr_2$	17.7	44.2	105.8	191.0	283.3	368.5			
$CdSO_4$	4.1	8.9	18.1						
CdI_2	7.6	14.8	33.5	52.7					
$CdBr_2$	8.6	17.8	36.7	55.7	80.0				
$CdCl_2$	9.6	18.8	36.7	57.0	77.3	99.0			
$Cd(NO_3)_2$	15.9	36.1	78.0	122.2					
$Cd(ClO_3)_2$	17.5								
$CoSO_4$	5.5	10.7	22.9	45.5					
$CoCl_2$	15.0	34.8	83.0	136.0	186.4				
$Co(NO_3)_2$	17.3	39.2	89.0	152.0	218.7	282.0	332.0		
$FeSO_4$	5.8	10.7	24.0	42.4					
H_3BO_3	6.0	12.3	25.1	38.0	51.0				
H_3PO_4	6.6	14.0	28.6	45.2	62.0	81.5	103.0	146.9	189.5
H_3AsO_4	7.3	15.0	30.2	46.4	64.9				
H_2SO_4	12.9	26.5	62.8	104.0	148.0	198.4	247.0	343.2	
KH_2PO_4	10.2	19.5	33.3	47.8	60.5	73.1	85.2		
KNO_3	10.3	21.1	40.1	57.6	74.5	88.2	102.1	126.3	148.0
$KClO_3$	10.6	21.6	42.8	62.1	80.0				
$KBrO_3$	10.9	22.4	45.0						
$KHSO_4$	10.9	21.9	43.3	65.3	85.5	107.8	129.2	170.0	
KNO_2	11.1	22.8	44.8	67.0	90.0	110.5	130.7	167.0	198.8
$KClO_4$	11.5	22.3							
KCl	12.2	24.4	48.8	74.1	100.9	128.5	152.2		
$KHCO_2$	11.6	23.6	59.0	77.6	104.2	132.0	160.0	210.0	255.0
KI	12.5	25.3	52.2	82.6	112.2	141.5	171.8	225.5	278.5
$K_2C_2O_4$	13.9	28.3	59.8	94.2	131.0				
K_2WO_4	13.9	33.0	75.0	123.8	175.4	226.4			
K_2CO_3	14.4	31.0	68.3	105.5	152.0	209.0	258.5	350.0	
KOH	15.0	29.5	64.0	99.2	140.0	181.8	223.0	309.5	387.8
K_2CrO_4	16.2	29.5	60.0						
$LiNO_3$	12.2	25.9	55.7	88.9	122.2	155.1	188.0	253.4	309.2
$LiCl$	12.1	25.5	57.1	95.0	132.5	175.5	219.5	311.5	393.5
$LiBr$	12.2	26.2	60.0	97.0	140.0	186.3	241.5	341.5	438.0
Li_2SO_4	13.3	28.1	56.8	89.0					
$LiHSO_4$	12.8	27.0	57.0	93.0	130.0	168.0			
LiI	13.6	28.6	64.7	105.2	154.5	206.0	264.0	357.0	445.0
Li_2SiFl_6	15.4	34.0	70.0	106.0					
$LiOH$	15.9	37.4	78.1						
Li_2CrO_4	16.4	32.6	74.0	120.0	171.0				

* Compiled from a table by Tammann, "Mém. Ac. St. Petersb." 35, No. 9, 1887. See also Referate, "Zeit. f. Phys." ch. 2, 42, 1886.

VAPOR PRESSURE OF SOLUTIONS OF SALTS IN WATER.

Substance.	0.5	1.0	2.0	3.0	4.0	5.0	6.0	8.0	10.0
$MgSO_4$	6.5	12.0	24.5	47.5					
$MgCl_2$	16.8	39.0	100.5	183.3	277.0	377.0			
$Mg(NO_3)_2$	17.6	42.0	101.0	174.8					
$MgBr_2$	17.9	44.0	115.8	205.3	298.5				
$MgH_2(SO_4)_2$	18.3	46.0	116.0						
$MnSO_4$	6.0	10.5	21.0						
$MnCl_2$	15.0	34.0	76.0	122.3	167.0	209.0			
NaH_2PO_4	10.5	20.0	36.5	51.7	66.8	82.0	96.5	126.7	157.1
$NaHSO_4$	10.9	22.1	47.3	75.0	100.2	126.1	148.5	189.7	231.4
$NaNO_3$	10.6	22.5	46.2	68.1	90.3	111.5	131.7	167.8	198.8
$NaClO_3$	10.5	23.0	48.4	73.5	98.5	123.3	147.5	196.5	223.5
$(NaPO_3)_6$	11.6								
$NaOH$	11.8	22.8	48.2	77.3	107.5	139.1	172.5	243.3	314.0
$NaNO_2$	11.6	24.4	50.0	75.0	98.2	122.5	146.5	189.0	226.2
$NaHPO_4$	12.1	23.5	43.0	60.0	78.7	99.8	122.1		
$NaHCO_2$	12.9	24.1	48.2	77.6	102.2	127.8	152.0	198.0	239.4
$NaSO_4$	12.6	25.0	48.9	74.2					
$NaCl$	12.3	25.2	52.1	80.0	111.0	143.0	176.5		
$NaBrO_3$	12.1	25.0	54.1	81.3	108.8	136.0			
$NaBr$	12.6	25.9	57.0	89.2	124.2	159.5	197.5	268.0	
NaI	12.1	25.6	60.2	99.5	136.7	177.5	221.0	301.5	370.0
$Na_4P_2O_7$	13.2	22.0							
Na_2CO_3	14.3	27.3	53.5	80.2	111.0				
$Na_2C_2O_4$	14.5	30.0	65.8	105.8	146.0				
Na_2WO_4	14.8	33.6	71.6	115.7	162.6				
Na_3PO_4	16.5	30.0	52.5						
$(NaPO_3)_3$	17.1	36.5							
NH_4NO_3	12.8	22.0	42.1	62.7	82.9	103.8	121.0	152.2	180.0
$(NH_4)_2SiFl_6$	11.5	25.0	44.5						
NH_4Cl	12.0	23.7	45.1	69.3	94.2	118.5	138.2	179.0	213.8
NH_4HSO_4	11.5	22.0	46.8	71.0	94.5	118.	139.0	181.2	218.0
$(NH_4)_2SO_4$	11.0	24.0	46.5	69.5	93.0	117.0	141.8		
NH_4Br	11.9	23.9	48.8	74.1	99.4	121.5	145.5	190.2	228.5
NH_4I	12.9	25.1	49.8	78.5	104.5	132.3	156.0	200.0	243.5
$NiSO_4$	5.0	10.2	21.5						
$NiCl_2$	16.1	37.0	86.7	147.0	212.8				
$Ni(NO_3)_2$	16.1	37.3	91.3	156.2	235.0				
$Pb(NO_3)_2$	12.3	23.5	45.0	63.0					
$Sr(SO_3)_2$	7.2	20.3	47.0						
$Sr(NO_3)_2$	15.8	31.0	64.0	97.4	131.4				
$SrCl_2$	16.8	38.8	91.4	156.8	223.3	281.5			
$SrBr_2$	17.8	42.0	101.1	179.0	267.0				
$ZnSO_4$	4.9	10.4	21.5	42.1	66.2				
$ZnCl_2$	9.2	18.7	46.2	75.0	107.0	153.0	195.0		
$Zn(NO_3)_2$	16.6	39.0	93.5	157.5	223.8				

PRESSURE OF AQUEOUS VAPOR AT LOW TEMPERATURE.*

Pressures are given in inches and millimetres of mercury, temperatures in degrees Fahrenheit and degrees Centigrade.

(a) Pressures in inches of mercury; temperatures in degrees Fahrenheit.

Temp. F.	0°.0	1°.0	2°.0	3°.0	4°.0	5°.0	6°.0	7°.0	8°.0	9°.0
—50°	0.0021	0.0019	0.0018	0.0017	0.0016	0.0015	0.0013	0.0013	0.0012	0.0011
—40	.0039	.0037	.0035	.0033	.0031	.0029	.0027	.0026	.0024	.0022
—30	.0069	.0065	.0061	.0057	.0054	.0051	.0048	.0046	.0044	.0041
—20	.0126	.0119	.0112	.0106	.0100	.0094	.0089	.0083	.0078	.0074
—10	.0222	.0210	.0199	.0188	.0178	.0168	.0159	.0150	.0141	.0133
—0	0.0383	0.0263	0.0244	0.0225	0.0307	0.0291	0.0275	0.0260	0.0247	0.0234
+0	.0383	.0403	.0423	.0444	.0467	.0491	.0515	.0542	.0570	.0600
10	.0631	.0665	.0699	.0735	.0772	.0810	.0850	.0891	.0933	.0979
20	.1026	.1077	.1130	.1185	.1242	.1302	.1365	.1430	.1497	.1568
30	.1641	.1718	.1798							

(b) Pressures in millimetres of mercury; temperatures in degrees Fahrenheit.

Temp. F.	0°.0	1°.0	2°.0	3°.0	4°.0	5°.0	6°.0	7°.0	8°.0	9°.0
—50°	0.053	0.049	0.046	0.043	0.040	0.037	0.034	0.032	0.030	0.028
—40	.100	.094	.089	.084	.079	.074	.069	.065	.061	.057
—30	.176	.165	.155	.146	.138	.130	.123	.117	.111	.105
—20	.319	.301	.284	.268	.253	.239	.225	.212	.199	.187
—10	.564	.534	.505	.478	.452	.427	.403	.384	.358	.338
—0°	0.972	0.922	0.873	0.826	0.781	0.738	0.698	0.661	0.627	0.595
+0	.972	1.023	1.075	1.129	1.186	1.246	1.309	1.376	1.447	1.523
10	1.603	1.688	1.776	1.867	1.961	2.058	2.158	2.262	2.371	2.486
20	2.607	2.735	2.869	3.009	3.155	3.307	3.466	3.631	3.803	3.982
30	4.169	4.364	4.568							

(c) Pressures in inches of mercury; temperatures in degrees Centigrade.

Temp. C.	0°.0	1°.0	2°.0	3°.0	4°.0	5°.0	6°.0	7°.0	8°.0	9°.0
—0°	0.1798	0.1655	0.1524	0.1395	0.1290	0.1185	0.1091	0.0998	0.0916	0.0842
—10	.0772	.0706	.0645	.0588	.0537	.0491	.0449	.0411	.0375	.0341
—20	.0307	.0278	.0252	.0229	.0208	.0188	.0171	.0153	.0138	.0124
—30	.0112	.0101	.0091	.0082	.0073	.0065	.0059	.0053	.0048	.0044
—40	.0040	.0036	.0032	.0029	.0025	.0022	.0020	.0017	.0015	.0013

(d) Pressures in millimetres of mercury; temperatures in degrees Centigrade.

Temp. C.	0°.0	1°.0	2°.0	3°.0	4°.0	5°.0	6°.0	7°.0	8°.0	9°.0
—0°	4.568	4.208	3.875	3.565	3.277	3.009	2.767	2.534	2.327	2.138
—10	1.961	1.794	1.637	1.493	1.363	1.246	1.140	1.044	0.952	0.864
—20	0.781	0.706	0.641	0.583	0.528	0.478	0.432	0.389	0.350	0.315
—30	0.284	0.256	0.231	0.207	0.185	0.165	0.148	0.133	0.121	0.110
—40	0.100	0.090	0.081	0.072	0.064	0.057	0.050	0.044	0.039	0.034

* Marvin's results (Ann. Rept. U. S. Chief Signal Officer, 1891, App. 10).

TABLE 136.

PRESSURE OF AQUEOUS VAPOR, 0° C TO 100° C.

According to Broch.*

Temp. °C.	0.0	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8
+0	4.57	4.64	4.70	4.77	4.84	4.91	4.98	5.05	5.12	5.20
2	5.27	5.35	5.42	5.50	5.58	5.66	5.74	5.82	5.90	5.99
4	6.07	6.15	6.24	6.33	6.42	6.51	6.60	6.69	6.78	6.88
6	6.97	7.07	7.17	7.26	7.36	7.47	7.57	7.67	7.78	7.88
8	7.99	8.10	8.21	8.32	8.43	8.55	8.66	8.78	8.90	9.02
10	9.14	9.26	9.39	9.51	9.64	9.77	9.90	10.03	10.16	10.30
12	10.43	10.57	10.71	20.85	10.99	11.14	11.28	11.43	11.58	11.73
14	11.88	12.04	12.19	12.35	12.51	12.67	12.84	13.00	13.17	13.34
16	13.51	13.68	13.86	14.04	14.21	14.40	14.58	14.76	14.95	15.14
18	15.33	15.52	15.72	15.92	16.12	16.32	16.52	16.73	16.94	17.15
20	17.36	17.58	17.80	18.02	18.24	18.47	18.69	18.92	19.16	19.39
22	19.63	19.87	20.11	20.36	20.61	20.86	21.11	21.37	21.63	21.89
24	22.15	22.42	22.69	22.96	23.24	23.52	23.80	24.08	24.37	24.66
26	24.96	25.25	25.55	25.86	26.16	26.47	26.78	27.10	27.42	27.74
28	28.07	28.39	28.73	29.06	29.40	29.74	30.09	30.44	30.79	31.15
30	31.51	31.87	32.24	32.61	32.99	33.37	33.75	34.14	34.53	34.92
32	35.32	35.72	36.13	36.54	36.95	37.37	37.79	38.22	38.65	39.08
34	39.52	39.97	40.41	40.87	41.32	41.78	42.25	42.72	43.19	43.67
36	44.16	44.65	45.14	45.64	46.14	46.65	47.16	47.68	48.20	48.73
38	49.26	49.80	50.34	50.89	51.44	52.00	52.56	53.13	53.70	54.28
40	54.87	55.46	56.05	56.65	57.26	57.87	58.49	59.11	59.74	60.38
42	61.02	61.66	62.32	62.98	63.64	64.31	64.99	65.67	66.36	67.05
44	67.76	68.47	69.18	69.90	70.63	71.36	72.10	72.85	73.60	74.36
46	75.13	75.91	76.69	77.47	78.27	79.07	79.88	80.70	81.52	82.35
48	83.19	84.03	84.89	85.75	86.61	87.49	88.37	89.26	90.16	91.06
50	91.98	92.90	93.83	94.77	95.71	96.66	97.63	98.60	99.57	100.56
52	101.55	102.56	103.57	104.59	105.62	106.65	107.70	108.76	109.82	110.89
54	111.97	113.06	114.16	115.27	116.39	117.52	118.65	119.80	120.95	122.12
56	123.29	124.48	125.67	126.87	128.09	129.31	130.54	131.79	133.04	134.30
58	135.58	136.86	138.15	139.46	140.77	142.10	143.43	144.78	146.14	147.51
60	148.88	150.27	151.68	153.09	154.51	155.95	157.39	158.85	160.32	161.80
62	163.29	164.79	166.31	167.83	169.37	170.92	172.49	174.06	175.65	177.25
64	178.86	180.48	182.12	183.77	185.43	187.10	188.79	190.49	192.20	193.93
66	195.67	197.42	199.18	200.96	202.75	204.56	206.38	208.21	210.06	211.92
68	213.79	215.68	217.58	219.50	221.43	223.37	225.33	227.30	229.29	231.29
70	233.31	235.34	237.39	239.45	241.52	243.62	245.72	247.85	249.98	252.14
72	254.30	256.49	258.69	260.91	263.14	265.38	267.65	269.93	272.23	274.54
74	276.87	279.21	281.58	283.95	286.35	288.76	291.19	293.64	296.11	298.59
76	301.09	303.60	306.14	308.69	311.26	313.85	316.45	319.07	321.72	324.38
78	327.05	329.75	332.47	335.20	337.95	340.73	343.52	346.33	349.16	352.01
80	354.87	357.76	360.67	363.59	366.54	369.51	372.49	375.50	378.53	381.58
82	384.64	387.73	390.84	393.97	397.12	400.29	403.49	406.70	409.94	413.19
84	416.47	419.77	423.09	426.44	429.81	433.19	436.60	440.04	443.49	446.97
86	450.47	454.00	457.54	461.11	464.71	468.32	471.96	475.63	479.32	483.03
88	486.76	490.52	494.31	498.12	501.95	505.81	509.69	513.60	517.53	521.48
90	525.47	529.48	533.51	537.57	541.65	545.77	549.90	554.07	558.26	562.47
92	566.71	570.98	575.28	579.61	583.96	588.33	592.74	597.17	601.64	606.13
94	610.64	615.19	619.76	624.37	629.00	633.66	638.35	643.06	647.81	652.59
96	657.40	662.23	667.10	672.00	676.92	681.88	686.87	691.89	696.93	702.02
98	707.13	712.27	717.44	722.65	727.89	733.16	738.46	743.80	749.17	754.57
100	760.00	765.47	770.97	776.50	782.07	787.67	–	–	–	–

* This table is based on Regnault's experiments, the numbers being taken from Broch's reduction of the observations (Trav. et Mém. du Bur. Int. des Poids et Més. tom. 1).

TABLE 137.

PRESSURE OF AQUEOUS VAPOR, 100° C. TO 230° C.

According to Regnault.

Temp. ° Cent.	Pressure : mm. of mercury.	Grammes per sq. centimetre.	Pounds per sq. inch.	Pressure : inches of mercury.	Pressure : atmospheres.	Temp. ° Fahr.	Temp. ° Cent.	Pressure : mm. of mercury.	Grammes per sq. centimetre.	Pounds per sq. inch.	Pressure : inches of mercury.	Pressure : atmospheres.	Temp. ° Fahr.
100	760.00	1033.26	14.70	29.92	1.000	**212.0**	**150**	3581.2	4868.9	69.26	141.0	4.712	**302.0**
101	787.59	1070.78	15.23	31.01	.036	213.8	151	3678.4	5001.1	71.14	144.8	.840	303.8
102	816.01	1109.41	15.79	32.13	.074	215.6	152	3777.7	5136.1	73.06	148.7	.971	305.6
103	845.28	1149.21	16.35	33.28	.112	217.4	153	3879.2	5275.0	75.02	152.7	5.104	307.4
104	875.41	1190.17	16.94	34.46	.152	219.2	154	3982.8	5414.8	77.03	156.8	.240	309.2
105	906.41	1232.32	17.53	35.69	1.193	**221.0**	**155**	4088.6	5558.6	79.07	161.0	5.380	**311.0**
106	938.31	1275.69	18.15	36.94	.235	222.8	156	4196.6	5705.5	81.22	165.2	.522	312.8
107	971.14	1320.32	18.78	38.23	.278	224.6	157	4306.9	5855.5	83.29	169.6	.667	314.6
108	1004.91	1366.24	19.44	39.56	.322	226.4	158	4419.5	6008.5	85.47	174.0	.815	316.4
109	1039.65	1413.47	20.11	40.93	368	228.2	159	4534.4	6164.7	87.69	178.5	.966	318.2
110	1075.37	1462.03	20.80	42.34	1.415	**230.0**	**160**	4651.6	6324.2	89.96	183.1	6.120	**320.0**
111	1112.09	1511.97	21.51	43.78	.463	231.8	161	4771.3	6486.8	92.27	187.9	.278	321.8
112	1149.83	1563.26	22.24	45.25	.513	233.6	162	4893.4	6652.8	94.63	192.7	.439	323.6
113	1188.61	1615.99	22.99	46.80	.564	235.4	163	5017.9	6822.2	97.04	197.6	.603	325.4
114	1228.47	1670.18	23.76	48.37	.616	237.2	164	5145.0	6994.9	99.50	202.6	.770	327.2
115	1269.41	1725.84	24.55	49.98	1.670	**239.0**	**165**	5274.5	7171.1	102.01	207.7	6.940	**329.0**
116	1311.47	1783.02	25.37	51.63	.726	240.8	166	5406.7	7350.7	104.56	212.9	7.114	330.8
117	1354.66	1841.74	26.20	53.34	.782	242.6	167	5541.4	7533.9	107.18	218.2	.291	332.6
118	1399.02	1902.05	27.06	55.08	.841	244.4	168	5678.8	7720.7	109.84	223.6	.472	334.4
119	1444.55	1963.95	27.94	56.87	.901	246.2	169	5818.9	7911.1	112.53	229.1	.656	336.2
120	1491.28	2027.48	28.85	58.71	1.962	**248.0**	**170**	5961.7	8105.2	115.29	234.1	7.844	**338.0**
121	1539.25	2092.70	29.78	60.61	2.025	249.8	171	6107.2	8303.1	118.11	240.4	8.036	339.8
122	1588.47	2159.62	30.73	62.54	.091	251.6	172	6255.5	8504.7	120.98	246.3	.231	341.6
123	1638.96	2228.26	31.70	64.53	.157	253.4	173	6406.6	8710.2	123.90	252.2	.430	343.4
124	1690.76	2298.69	32.70	66.56	.225	255.2	174	6560.6	8919.5	126.87	258.3	.632	345.2
125	1743.88	2370.91	33.72	68.66	2.295	**257.0**	**175**	6717.4	9132.8	129.91	264.5	8.839	**347.0**
126	1798.35	2444.96	34.78	70.80	.366	258.8	176	6877.2	9350.0	133.00	270.8	9.049	348.8
127	1854.20	2520.89	35.86	73.00	.430	260.6	177	7040.0	9571.3	136.15	277.2	.263	350.6
128	1911.47	2598.76	36.97	75.25	.515	262.4	178	7205.7	9796.6	139.35	283.7	.481	352.4
129	1970.15	2678.54	38.11	77.57	.592	264.2	179	7374.5	10026.1	142.62	290.3	.703	354.2
130	2030.28	2760.29	39.26	79.93	2.671	**266.0**	**180**	7546.4	10259.7	145.93	297.1	9.929	**356.0**
131	2091.94	2844.12	40.47	82.36	.753	267.8	181	7721.4	10497.7	149.32	304.0	10.150	357.8
132	2155.03	2929.89	41.68	84.84	.836	269.6	182	7899.5	10739.9	152.77	311.0	.394	359.6
133	2219.69	3017.80	42.93	87.39	.921	271.4	183	8080.8	10986.4	156.32	318.1	.633	361.4
134	2285.92	3107.85	44.21	89.99	3.008	273.2	184	8265.4	11237.3	159.84	325.4	.876	363.2
135	2353.73	3200.04	45.52	92.67	3.097	**275.0**	**185**	8453.2	11490.0	163.47	332.3	11.123	**365.0**
136	2423.16	3294.43	46.87	95.39	.188	276.8	186	8644.4	11752.5	167.17	340.3	.374	366.8
137	2494.23	3391.06	48.24	98.19	.282	278.6	187	8838.8	12016.9	170.94	348.0	.630	368.6
138	2567.00	3489.99	49.65	101.06	.378	280.4	188	9036.7	12285.9	174.76	355.8	.885	370.4
139	2641.44	3591.29	51.06	103.99	.476	282.2	189	9238.0	12559.6	178.65	363.7	12.155	372.2
140	2717.63	3694.78	52.55	106.99	3.576	**284.0**	**190**	9442.7	12837.9	182.61	371.8	12.425	**374.0**
141	2795.57	3800.75	54.07	110.06	.678	285.8	191	9650.9	13121.0	186.63	380.0	12.699	375.8
142	2875.30	3909.14	55.60	113.20	.783	287.6	192	9862.7	13408.9	190.72	388.3	12.977	377.6
143	2956.86	4020.03	57.16	116.41	.890	289.4	193	10078.0	13701.7	194.88	396.8	13.261	379.4
144	3040.26	4133.42	58.79	119.69	4.000	291.2	194	10297.0	13999.4	199.13	405.4	13.549	381.2
145	3125.55	4249.37	60.44	123.05	4.113	**293.0**	**195**	10519.6	14302.7	203.43	414.1	13.842	**383.0**
146	3212.74	4367.91	62.13	126.48	.227	294.8	196	10746.0	14609.8	207.81	423.1	14.139	384.8
147	3301.87	4489.09	63.86	129.99	.344	296.6	197	10975.0	14921.2	212.25	432.1	14.441	386.6
148	3392.98	4612.96	65.62	133.58	.464	298.4	198	11209.8	15240.4	216.77	441.3	14.749	388.4
149	3486.09	4739.55	67.41	137.25	.587	300.2	199	11447.5	15563.5	221.37	450.7	15.062	390.2

PRESSURE AND WEIGHT OF AQUEOUS VAPOR.

TABLE 137 (*continued*). — **Pressure of Aqueous Vapor, 100° 0–230° 0.**

According to Regnault.

Temp. ° Cent.	Pressure : mm. of mercury.	Grammes per sq. centimetre.	Pounds per sq. inch.	Pressure : inches of mercury.	Pressure : atmospheres.	Temp. ° Fahr.	Temp. ° Cent.	Pressure : mm. of mercury.	Grammes per sq. centimetre.	Pounds per sq. inch.	Pressure : inches of mercury.	Pressure : atmospheres.	Temp. ° Fahr.
200	11689.0	15891.9	226.04	460.1	15.380	**392.0**	**215**	15801.3	21482.8	305.57	622.1	20.791	**419.0**
201	11934.4	16225.5	230.79	469.8	15.703	393.8	216	16109.9	21902.4	311.57	634.2	21.197	420.8
202	12183.7	16564.7	235.61	479.7	16.031	395.6	217	16423.2	22328.3	317.62	646.6	21.690	422.6
203	12437.0	16908.8	240.54	489.6	16.364	397.4	218	16740.9	22760.3	323.78	659.1	22.027	424.4
204	12694.3	17257.3	245.49	499.8	16.703	399.2	219	17063.3	23198.6	330.01	671.8	22.452	426.2
205	12955.7	17614.0	250.53	510.1	17.047	**401.0**	**220**	17390.4	23643.2	336.30	684.7	22.882	**428.0**
206	13221.1	17974.9	255.67	520.5	17.396	402.8	221	17722.1	24094.3	342.70	697.7	23.319	429.8
207	13490.8	18341.5	260.88	531.2	17.751	404.6	222	18058.6	24551.8	349.21	711.0	23.761	431.6
208	13764.5	18713.7	266.18	541.9	18.111	406.4	223	18399.9	25015.8	355.81	724.4	24.210	433.4
209	14042.5	19091.6	271.55	552.9	18.477	408.2	224	18746.1	25486.4	362.50	738.0	24.666	435.2
210	14324.8	19475.4	277.01	564.1	18.848	**410.0**	**225**	19097.0	25963.5	369.29	751.9	25.128	**437.0**
211	14611.3	19864.9	282.58	575.3	19.226	411.8	226	19452.9	26447.4	376.17	765.8	25.596	438.8
212	14902.2	20260.5	288.21	586.7	19.608	413.6	227	19813.8	26938.0	383.15	780.9	26.071	440.6
213	15197.5	20661.9	293.92	598.3	19.997	415.4	228	20179.6	27435.4	390.22	794.5	26.552	442.4
214	15497.2	21069.3	299.72	610.2	20.391	417.2	229	20550.5	27939.6	397.40	809.0	27.040	444.2

TABLE 138. — Weight in Grains of the Aqueous Vapor contained in a Cubic Foot of Saturated Air.*

Temp. ° F.	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0
—10	0.285	0.270	0.257	0.243	0.231	0.218	0.207	0.196	0.184	0.174
—0	0.481	0.457	0.434	0.411	0.389	0.370	0.350	0.332	0.316	0.300
+0	0.481	0.505	0.529	0.554	0.582	0.610	0.639	0.671	0.704	0.739
10	0.776	0.816	0.856	0.898	0.941	0.985	1.032	1.079	1.128	1.181
20	1.235	1.294	1.355	1.418	1.483	1.551	1.623	1.697	1.773	1.853
30	1.935	2.022	2.113	2.194	2.279	2.366	2.457	2.550	2.646	2.746
40	2.849	2.955	3.064	3.177	3.294	3.414	3.539	3.667	3.800	3.936
50	4.076	4.222	4.372	4.526	4.685	4.849	5.018	5.191	5.370	5.555
60	5.745	5.941	6.142	6.349	6.563	6.782	7.009	7.241	7.480	7.726
70	7.980	8.240	8.508	8.782	9.066	9.356	9.655	9.962	10.277	10.601
80	10.934	11.275	11.626	11.987	12.356	12.736	13.127	13.526	13.937	14.359
90	14.790	15.234	15.689	16.155	16.634	17.124	17.626	18.142	18.671	19.212
100	19.766	20.335	20.917	21.514	22.125	22.750	23.392	24.048	24.720	25.408
110	26.112	26.832	27.570	28.325	29.096	29.887	–	–	–	–

* See "Smithsonian Meteorological Tables," pp. 132–133.

TABLE 139. — Weight in Grammes of the Aqueous Vapor contained in a Cubic Metre of Saturated Air.

Temp. ° C.	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0
—20	0.892	0.810	0.737	0.673	0.613	0.557	0.505	0.457	0.413	0.373
—10	2.154	1.978	1.811	1.658	1.519	1.395	1.282	1.177	1.079	0.982
—0	4.835	4.468	4.130	3.813	3.518	3.244	2.988	2.752	2.537	2.340
+0	4.835	5.176	5.538	5.922	6.330	6.761	7.219	7.703	8.215	8.757
10	9.330	9.935	10.574	11.249	11.961	12.712	13.505	14.339	15.218	16.144
20	17.118	18.143	19.222	20.355	21.546	22.796	24.109	25.487	26.933	28.450
30	30.039	31.704	33.449	35.275	37.187	39.187	41.279	43.465	45.751	48.138

PRESSURE OF AQUEOUS VAPOR IN THE ATMOSPHERE.

This table gives the vapor pressure corresponding to various values of the difference $t - t_1$ between the readings of dry and wet bulb thermometers and the temperature t_1 of the wet bulb thermometer. The differences $t - t_1$ are given by two-degree steps in the top line, and t_1 by degrees in the first column. Temperatures in Centigrade degrees and Regnault's vapor pressures in millimetres of mercury are used throughout the table. The table was calculated for barometric pressure B equal to 76 centimetres, and a correction is given for each centimetre at the top of the columns.*

t_1	$t-t_1=0$	2	4	6	8	10	12	14	16	18	20	Difference per 1° of $t-t_1$
Corrections for B per centimetre.†		.013	.026	.040	.053	.066	.079	.092	.106	.119	.132	
—10	1.96	0.96										**0.100**
—9	2.14	1.14	0.14									0.100
—8	2.33	1.33	0.33									0.100
—7	2.53	1.53	0.53									0.100
—6	2.76	1.76	0.76									0.100
—5	3.01	2.01	1.00									**0.100**
—4	3.28	2.28	1.27	0.27								0.100
—3	3.57	2.57	1.56	0.56								0.100
—2	3.88	2.88	1.87	0.87								0.100
—1	4.22	3.22	2.21	1.21	0.21							0.100
0	4.60	3.60	2.59	1.59	0.59							**0.100**
1	4.94	3.93	2.92	1.92	0.92							0.100
2	5.30	4.29	3.29	2.28	1.28	0.27						0.100
3	5.69	4.68	3.68	2.67	1.66	0.66						0.101
4	6.10	5.09	4.09	3.08	2.07	1.06	0.05					0.101
5	6.53	5.52	4.51	3.50	2.49	1.48	0.48					**0.101**
6	7.00	5.99	4.98	3.97	2.96	1.95	0.94					0.101
7	7.49	6.48	5.47	4.45	3.44	2.43	1.42	0.41				0.101
8	8.02	7.01	5.99	4.98	3.97	2.96	1.94	0.93				0.101
9	8.57	7.56	6.54	5.53	4.51	3.50	2.49	1.48	0.46			0.101
10	9.17	8.16	7.14	6.12	5.11	4.09	3.08	2.07	1.06	0.05		**0.101**
11	9.79	8.77	7.76	6.74	5.73	4.71	3.69	2.68	1.66	0.64		0.102
12	10.46	9.44	8.43	7.41	6.39	5.37	4.36	3.34	2.32	1.30	0.28	0.102
13	11.16	10.14	9.12	8.10	7.09	6.07	5.05	4.03	3.01	1.99	0.97	0.102
14	11.91	10.89	9.87	8.85	7.83	6.81	5.79	4.77	3.71	2.69	1.67	0.102
15	12.70	11.68	10.66	9.64	8.62	7.60	6.58	5.56	4.54	3.52	2.50	**0.102**
16	13.54	12.52	11.50	10.47	9.45	8.43	7.41	6.39	5.37	4.35	3.33	0.102
17	14.42	13.40	12.37	11.35	10.33	9.31	8.28	7.26	6.24	5.22	4.20	0.102
18	15.36	14.34	13.31	12.29	11.26	10.24	9.21	8.19	7.17	6.15	5.13	0.102
19	16.35	15.33	14.30	13.27	12.25	11.22	10.20	9.17	8.15	7.13	6.11	0.102
20	17.39	16.37	15.34	14.31	13.28	12.26	11.23	10.21	9.18	8.15	7.12	**0.103**
21	18.50	17.47	16.45	15.42	14.39	13.36	12.33	11.31	10.28	9.25	8.22	0.103
22	19.66	18.63	17.60	16.57	15.54	14.51	13.48	12.46	11.43	10.40	9.37	0.103
23	20.89	19.86	18.83	17.80	16.77	15.74	14.71	13.68	12.66	11.63	10.60	0.103
24	22.18	21.15	20.12	19.09	18.05	17.02	15.99	14.96	13.94	12.91	11.88	0.103
25	23.55	22.52	21.49	20.45	19.43	18.39	17.36	16.33	15.30	14.27	13.24	**0.103**
26	24.99	23.96	22.92	21.89	20.86	19.82	18.79	17.76	16.73	15.70	14.67	0.103
27	26.51	25.48	24.44	23.40	22.37	21.34	20.30	19.27	18.24	17.21	16.18	0.103
28	28.10	27.07	26.03	24.99	23.96	22.92	21.89	20.85	19.82	18.79	17.76	0.103
29	29.78	28.75	27.71	26.67	25.63	24.59	23.56	22.52	21.49	20.46	19.43	0.103
30	31.55	30.51	29.47	28.43	27.40	26.36	25.32	24.29	23.25	22.22	21.18	**0.104**
31	33.41	32.37	31.33	30.29	29.25	28.22	27.18	26.14	25.10	24.07	23.03	0.104
32	35.36	34.32	33.28	32.24	31.21	30.17	29.13	28.09	27.05	26.01	24.97	0.104
33	37.41	36.37	35.33	34.29	33.25	32.22	31.18	30.14	29.10	28.06	27.02	0.104
34	39.57	38.53	37.48	36.44	35.40	34.36	33.32	32.28	31.24	30.20	29.16	0.104
35	41.83	40.79	39.74	38.70	37.66	36.62	35.68	34.64	33.60	32.56	31.52	**0.104**
36	44.20	43.16	42.11	41.07	40.03	38.99	37.95	36.90	35.86	34.82	33.78	0.104
37	46.69	45.65	44.60	43.56	42.52	41.48	40.44	39.39	38.35	37.31	36.27	0.104
38	49.30	48.26	47.21	46.17	45.13	44.08	43.04	41.99	40.95	39.91	38.87	0.104
39	52.04	51.00	49.95	48.91	47.86	46.82	45.77	44.73	43.78	42.74	41.69	0.105

Example.

$t - t_1 = 7.2$
$t_1 = 10.0$
$B = 74.5$
Tabular number $= 6.12 - 6 \times .101 = 5.51$
Correction for $B = 1.5 \times .048 \ldots = .07$
Hence we get $p \ldots = 5.58$

* The table was calculated from the formula $p = p_1 - 0.00066\, B\,(t - t_1)\,(1 + 0.00115\, t_1)$ (Ferrel, Annual Report U. S. Chief Signal Officer, 1886, App. 24).

† When B is less than 76 the correction is to be added, and when B is greater than 76 it is to be subtracted.

The first column of this table gives the temperatures of the wet-bulb thermometer, and the top line the differenc
the table. The dew-points were computed for a barometric pressure of 76 centimetres. When the barometer differ
and the resulting number added to or subtracted from the tabular number according as the barometer is below o

t_1	$t-t_1=1$	2	3	4	5	6	7	8
	Dew-points corresponding to the difference of temperature given in the above line and the wet-bulb thermometer reading given in first column.							
$\delta T/\delta B=$	.04	.11	.22	.49				
−10	−13.2	−17.9						
−9	12.0	16.0	−22.0					
−8	10.7	14.3	19.4					
−7	9.5	12.7	17.1	−24.0				
−6	8.3	11.2	14.9	20.3				
$\delta T/\delta B=$	.03	.06	.11	.18	.31	.43		
−5	−7.1	−9.7	−12.9	−17.5	−24.5			
−4	6.0	8.3	11.1	14.8	20.1			
−3	4.8	6.9	9.4	12.6	16.8	−23.4		
−2	3.6	5.5	7.8	10.5	13.9	18.9		
−1	2.5	4.2	6.2	8.5	11.5	15.4	−21.0	
$\delta T/\delta B=$	.02	.04	.07	.10	.14	.19	.26	.38
0	−1.3	−2.9	−4.8	−6.8	−9.3	−12.3	−16.5	−22.9
1	0.3	1.7	3.5	5.3	7.6	10.2	13.5	18.3
2	+0.6	0.7	2.2	3.9	6.1	8.3	11.1	14.7
3	1.7	+0.2	1.0	2.6	4.6	6.4	8.9	11.9
4	2.8	1.4	0.0	1.3	3.1	4.7	6.9	9.4
$\delta T/\delta B=$	.02	.03	.05	.07	.09	.11	.14	.18
5	3.8	2.6	+1.2	−0.1	−1.6	−3.2	−5.0	−7.1
6	4.9	3.7	2.5	+1.1	0.2	1.7	3.3	5.2
7	6.0	4.9	3.7	2.4	+1.1	0.3	1.8	3.4
8	7.0	6.0	4.9	3.7	2.5	+1.1	0.3	1.8
9	8.1	7.1	6.1	5.0	3.9	2.6	+1.2	0.1
$\delta T/\delta B=$	.01	.02	.03	.05	.06	.08	.10	.12
10	9.1	8.3	7.3	6.3	5.2	4.1	2.8	+1.5
11	10.2	9.3	8.4	7.5	6.5	5.5	4.3	3.1
12	11.2	10.4	9.6	8.7	7.8	6.8	5.8	4.7
13	12.3	11.5	10.7	9.9	9.1	8.2	7.2	6.2
14	13.3	12.6	11.9	11.1	10.3	9.05	8.6	7.6
$\delta T/\delta B=$	.01	.02	.03	.04	.05	.06	.07	.08
15	14.4	13.7	13.0	12.3	11.5	10.8	9.9	9.1
16	15.4	14.8	14.1	13.5	12.7	12.0	11.3	10.5
17	16.4	15.8	15.2	14.6	13.9	13.3	12.6	11.8
18	17.5	16.9	16.3	15.7	15.1	14.5	13.8	13.1
19	18.5	18.0	17.4	16.9	16.3	15.7	15.1	14.4
$\delta T/\delta B=$	.005	.01	.015	.02	.027	.033	.04	.05
20	19.5	19.0	18.5	18.0	17.4	16.9	16.3	15.7
21	20.5	20.1	19.6	19.1	18.6	18.1	17.5	17.0
22	21.6	21.1	20.7	20.2	19.7	19.2	18.7	18.2
23	22.6	22.2	21.7	21.3	20.8	20.4	19.9	19.4
24	23.6	23.2	22.8	22.4	22.0	21.5	21.1	20.6
$\delta T/\delta B=$	.005	.01	.015	.02	.025	.03	.035	.04
25	24.6	24.2	23.9	23.5	23.1	22.7	22.2	21.8
26	25.6	25.3	24.9	24.5	24.2	23.8	23.4	23.0
27	26.7	26.3	26.0	25.6	25.3	24.9	24.5	24.1
28	27.7	27.3	27.0	26.7	26.4	26.0	25.7	25.3
29	28.7	28.4	28.1	27.8	27.4	27.1	26.8	26.4
$\delta T/\delta B=$	.003	.006	.01	.013	.017	.019	.022	.026
30	29.7	29.4	29.1	28.8	28.5	28.2	27.9	27.6
31	30.7	30.5	30.2	29.9	29.6	29.3	29.0	28.7
32	31.7	31.5	31.2	30.9	30.7	30.4	30.1	29.8
33	32.8	32.5	32.2	32.0	31.7	31.5	31.2	30.9
34	33.8	33.5	33.3	33.0	32.8	32.5	32.3	32.0
$\delta T/\delta B=$	.003	.005	.008	.010	.013	.016	.019	.021
35	34.8	34.5	34.3	34.1	33.8	33.6	33.4	33.1
36	35.8	35.5	35.3	35.1	34.9	34.6	34.4	34.2
37	36.8	36.6	36.4	36.2	36.0	35.7	35.5	35.3
38	37.8	37.6	37.4	37.2	37.0	36.8	36.6	36.4
39	38.8	38.6	38.4	38.2	38.0	37.9	37.6	37.5

POINTS.

between the dry and the wet bulb, when the dew-point has the values given at corresponding points in the body of from 76 centimetres the corresponding numbers in the lines marked $\delta T/\delta B$ are to be multiplied by the difference, or above 76. See examples.

t_1	$t-t_1=9$	10	11	12	13	14	15
	Dew-points corresponding to the difference of temperature given in the above line and the wet-bulb thermometer reading given in first column.						
			EXAMPLES.				
			(1) Given $B=72$, $t_1=10$, $t-t_1=5$.				
			Then tabular number for $t_1=10$ and $t-t_1=5$ is 5.2				
			Also $76-72=4$ and $\delta T/\delta B=.06$.				
			$\therefore$ Correction $=0.06\times4=$ 24				
			Hence the dew-point is 5.44				
			(2) Given $B=71.5$, $t_1=7$, $t-t_1=8$.				
			Then, as above, tabulated number = . . 3.4				
			$\delta T/\delta B=\frac{.18+.12}{2}=.15$				
			Correction $=0.15\times4.5=$ 67				
			Dew-point = ... 4.07				
$\delta T/\delta B=$	.45	.67					
0							
1							
2	−20.0						
3	15.8	−22.2					
4	12.4	16.8					
$\delta T/\delta B=$	.23	.29	.37	.44	.54	.66	.72
5	−19.8	−13.1	−17.7				
6	7.4	10.1	13.4	−18.1			
7	5.3	7.6	10.1	13.5	−18.3		
8	3.3	5.2	7.4	10.1	13.5	−18.3	
9	1.6	3.2	5.1	7.2	9.9	13.1	−17.2
$\delta T/\delta B=$	.14	.17	.20	.22	.25	.29	.36
10	0.0	−1.3	−3.0	−4.7	−6.8	−9.4	−12.5
11	+1.8	+0.3	1.0	2.6	4.3	6.3	8.8
12	3.5	2.2	+0.8	0.6	2.1	3.7	5.7
13	5.1	3.9	2.7	+1.3	0.1	1.6	3.1
14	6.7	5.6	4.5	3.3	+1.9	+0.5	0.9
$\delta T/\delta B=$	.09	.11	.12	.14	.16	.18	.20
15	8.2	7.2	6.2	5.1	3.9	2.7	+1.3
16	9.6	8.7	7.8	6.8	5.8	4.7	3.5
17	11.0	10.2	9.4	8.5	7.5	6.5	5.5
18	12.4	11.7	10.9	10.1	9.2	8.3	7.4
19	13.8	13.1	12.4	11.6	10.8	10.0	9.1
$\delta T/\delta B=$	.06	.07	.08	.09	.10	.11	.13
20	15.1	14.5	13.8	13.1	12.4	11.6	10 8
21	16.4	15.8	15.2	14.5	13.9	13.2	12.5
22	17.6	17.1	16.5	15.9	15.3	14.7	14.0
23	18.9	18.4	17.9	17.3	16.8	16.2	15.7
24	20.1	19.6	19.2	18.7	18.1	17.6	17.0
$\delta T/\delta B=$	.045	.05	.06	.06	.07	.08	.09
25	21.4	20.9	20.4	20.0	19.5	19.0	18.5
26	22.6	22.1	21.7	21.3	20.8	20.3	19.9
27	23.7	23.4	22.9	22.5	22.1	21.7	21.2
28	24.9	24.5	24.2	23.8	23.4	23.0	22.6
29	26.1	25.7	25.4	25.0	24.6	24.2	23.9
$\delta T/\delta B=$	.031	.035	.041	.047	.053	.06	.07
30	27.2	26.9	26.6	26.2	25.9	25.5	25.2
31	28.4	28.1	27.8	27.4	27.1	26.8	26.4
32	29.5	29.2	28.9	28.6	28.3	28.0	27.7
33	30.7	30.4	30.1	29.8	29.5	29.2	28.9
34	31.8	31.5	31.2	30.9	30.7	30.4	30.1
$\delta T/\delta B=$	.024	.027	.029	.032	.037	.037	.04
35	32.9	32.6	32.4	32.1	31.8	31.6	31.4
36	34.0	33.7	33.5	33.3	33.0	32.8	32.5
37	35.1	34.9	34.6	34.4	34.2	33.9	33.7
38	36.2	35.9	35.7	35.5	35.3	35.1	34.8
39	37.3	37.1	36.8	36.6	36.4	36.2	36.0

RELATIVE HUMIDITY.*

This table gives the humidity of the air, for temperature t and dew-point d in Centigrade degrees, expressed in percentages of the saturation value for the temperature t.

Depression of the dew-point. $t-d$	Dew-point (d).					Depression of the dew-point. $t-d$	Dew-point (d).				
	−10	0	+10	+20	+30		−10	0	+10	+20	+30
C.						C.					
0°.0	100	100	100	100	100	8°.0	54	57	60	62	64
0.2	98	99	99	99	99	8.2	54	56	59	61	63
0.4	97	97	97	98	98	8.4	53	56	58	60	63
0.6	95	96	96	96	97	8.6	52	55	57	60	62
0.8	94	94	95	95	96	8.8	51	54	57	59	61
1.0	92	93	94	94	94	9.0	51	53	56	58	61
1.2	91	92	92	93	93	9.2	50	53	55	58	60
1.4	90	90	91	92	92	9.4	49	52	55	57	59
1.6	88	89	90	91	91	9.6	48	51	54	56	59
1.8	87	88	89	90	90	9.8	48	51	53	56	58
2.0	86	87	88	88	89	10.0	47	50	53	55	57
2.2	84	85	86	87	88	10.5	45	48	51	54	
2.4	83	84	85	86	87	11.0	44	47	49	52	
2.6	82	83	84	85	86	11.5	42	45	48	51	
2.8	80	82	83	84	85	12.0	41	44	47	49	
3.0	79	81	82	83	84	12.0	39	42	45	48	
3.2	78	80	81	82	83	13.0	38	41	44	46	
3.4	77	79	80	81	82	13.5	37	40	43	45	
3.6	76	77	79	80	82	14.0	35	38	41	44	
3.8	75	76	78	79	81	14.5	34	37	40	43	
4.0	73	75	77	78	80	15.0	33	36	39	42	
4.2	72	74	76	77	79	15.5	32	35	38	40	
4.4	71	73	75	77	78	16.0	31	34	37	39	
4.6	70	72	74	76	77	16.5	30	33	36	38	
4.8	69	71	73	75	76	17.0	29	32	35	37	
5.0	68	70	72	74	75	17.5	28	31	34	36	
5.2	67	69	71	73	75	18.0	27	30	33	35	
5.4	66	68	70	72	74	18.5	26	29	32	34	
5.6	65	67	69	71	73	19.0	25	28	31	33	
5.8	64	66	69	70	72	19.5	24	27	30	33	
6.0	63	66	68	70	71	20.0	24	26	29	32	
6.2	62	65	67	69	71	21.0	22	25	27		
6.4	61	64	66	68	70	22.0	21	23	26		
6.6	60	63	65	67	69	23.0	19	22	24		
6.8	60	62	64	66	68	24.0	18	21	23		
7.0	59	61	63	66	68	25.0	17	19	22		
7.2	58	60	63	65	67	26.0	16	18	21		
7.4	57	60	62	64	66	27.0	15	17	20		
7.6	56	59	61	63	65	28.0	14	16	19		
7.8	55	58	60	63	65	29.0	13	15	18		
8.0	54	57	60	62	64	30.0	12	14	17		

* Abridged from Table 45 of "Smithsonian Meteorological Tables."

VALUES OF 0.378e.*

This table gives the humidity term 0.378e, which occurs in the equation $\delta = \delta_0 \frac{h}{760} = \delta_0 \frac{B - 0.378e}{760}$ for the calculation of the density of the dry air in a sample containing aqueous vapor at pressure e; δ_0 is the density at normal barometric pressure, B the observed barometric pressure, and h the pressure corrected for humidity. For values of $\frac{h}{760}$ see Table 144. Temperatures are in degrees Centigrade, and pressures in millimetres of mercury.

Dew Point. °C.	e Vapor Pressure (ice).	0.378e.	Dew Point. °C.	e Vapor Pressure (water).	0.378e.	Dew Point. °C.	e Vapor Pressure (water).	0.378e.
−50	0.034	0.01	0	4.579	1.73	+30	31.555	11.93
45	.061	.02	+1	4.921	1.86	31	33.416	12.63
40	.105	.04	2	5.286	2.00	32	35.372	13.37
35	.173	.07	3	5.675	2.15	33	37.427	14.15
30	.292	.11	4	6.088	2.30	34	39.586	14.96
−25	0.484	0.18	5	6.528	2.47	35	41.853	15.82
24	.534	.20	6	6.997	2.65	36	44.23	16.72
23	.589	.22	7	7.494	2.83	37	46.73	17.66
22	.648	.24	8	8.023	3.03	38	49.35	18.65
21	.714	.27	9	8.584	3.24	39	52.09	19.69
−20	0.787	0.30	10	9.179	3.47	40	54.97	20.78
19	.868	.33	11	9.810	3.71	41	57.98	21.92
18	.955	.36	12	10.479	3.96	42	61.13	23.12
17	1.048	.40	13	11.187	4.23	43	64.43	24.35
16	1.148	.44	14	11.936	4.51	44	67.89	25.66
−15	1.257	0.48	15	12.728	4.81	45	71.50	27.02
14	1.375	.52	16	13.565	5.13	46	75.28	28.46
13	1.506	.57	17	14.450	5.46	47	79.23	29.95
12	1.650	.62	18	15.383	5.82	48	83.36	31.51
11	1.806	.68	19	16.367	6.19	49	87.67	33.14
−10	1.974	0.75	20	17.406	6.58	50	92.17	34.84
9	2.154	.81	21	18.503	6.99	51	96.87	36.62
8	2.347	.89	22	19.661	7.43	52	101.77	38.47
7	2.557	.97	23	20.883	7.90	53	106.88	40.40
6	2.785	1.05	24	22.178	8.38	54	112.21	42.42
−5	3.032	1.15	25	23.546	8.90	55	117.77	44.52
4	3.299	1.25	26	24.987	9.45	56	123.56	46.71
3	3.586	1.36	27	26.505	10.02	57	129.59	48.98
2	3.894	1.47	28	28.103	10.62	58	135.87	51.36
1	4.223	1.60	29	29.785	11.26	59	142.41	53.83
0	4.579	1.73	30	31.555	11.93	60	149.21	56.40

* This table is quoted from "Smithsonian Meteorological Tables," p. 225.

DENSITY OF AIR FOR DIFFERENT PRESSURES AND HUMIDITIES

TABLE 144.—Values of $\frac{h}{760}$, from $h = 1$ to $h = 9$, for the Computation of Different Values of the of Actual to Normal Barometric Pressure.

This gives the density of air at pressure h in terms of the density at normal atmosphere pressure. When contains moisture, as is usually the case with the atmosphere, we have the following equation for the pressure: $h = B - 0.378e$, where e is the vapor pressure, and B the observed barometric pressure correc temperature. When the necessary observations are made the value of e may be taken from Table 170, a $0.378e$ from Table 172, or the dew-point may be found and the value of $0.378e$ taken from Table 172.

h	$\frac{h}{760}$
1	0.0013158
2	.0026316
3	.0039474
4	0.0052632
5	.0065789
6	.0078947
7	0.0092105
8	.0105263
9	.0118421

EXAMPLES OF USE OF THE TABLE.

To find the value of $\frac{h}{760}$ when $h = 754.3$

$h = 700$	gives	.92105
50	"	.065789
4	"	.005263
.3	"	.000395
754.3		.992497

To find the value of $\frac{h}{760}$ when $h = 5.73$

$h = 5$	gives	.0065789
.7	"	.0007895
.03	"	.0000395
5.73		.0074079

TABLE 145.—Values of the logarithms of $\frac{h}{760}$ for values of h between 80 and 340.

Values from 8 to 80 may be got by subtracting 1 from the characteristic, and from 0.8 to 8 by subtracting 2 fr characteristic, and so on.

h	Values of $\log \frac{h}{760}$									
	0	1	2	3	4	5	6	7	8	
80	$\bar{1}$.02228	$\bar{1}$.02767	$\bar{1}$.03300	$\bar{1}$.03826	$\bar{1}$.04347	$\bar{1}$.04861	$\bar{1}$.05368	$\bar{1}$.05871	$\bar{1}$.06367	$\bar{1}$.06
90	.07343	.07823	.08297	.08767	.09231	.09691	.10146	.10596	.11041	.11
100	$\bar{1}$.11919	$\bar{1}$.12351	$\bar{1}$.12779	$\bar{1}$.13202	$\bar{1}$.13622	$\bar{1}$.14038	$\bar{1}$.14449	$\bar{1}$.14857	$\bar{1}$.15261	$\bar{1}$.15
110	.16058	.16451	.16840	.17226	.17609	.17988	.18364	.18737	.19107	.19
120	.19837	.20197	.20555	.20909	.21261	.21611	.21956	.22299	.22640	.22
130	.23313	.23646	.23976	.24304	.24629	.24952	.25273	.25591	.25907	.26
140	.26531	.26841	.27147	.27452	.27755	.28055	.28354	.28650	.28945	.29
150	$\bar{1}$.29528	$\bar{1}$.29816	$\bar{1}$.30103	$\bar{1}$.30388	$\bar{1}$.30671	$\bar{1}$.30952	$\bar{1}$.31231	$\bar{1}$.31509	$\bar{1}$.31784	$\bar{1}$.32
160	.32331	.32601	.32870	.33137	.33403	.33667	.33929	.34190	.34450	.34
170	.34964	.35218	.35471	.35723	.35974	.36222	.36470	.36716	.36961	.37
180	.37446	.37686	.37926	.38164	.38400	.38636	.38870	.39128	.39334	.39
190	.39794	.40022	.40249	.40474	.40699	.40922	.41144	.41365	.41585	.41
200	$\bar{1}$.42022	$\bar{1}$.42238	$\bar{1}$.42454	$\bar{1}$.42668	$\bar{1}$.42882	$\bar{1}$.43094	$\bar{1}$.43305	$\bar{1}$.43516	$\bar{1}$.43725	$\bar{1}$.43
210	.44141	.44347	.44552	.44757	.44960	.45162	.45364	.45565	.45764	.45
220	.46161	.46358	.46554	.46749	.46943	.47137	.47329	.47521	.47712	.47
230	.48091	.48280	.48467	.48654	.48840	.49025	.49210	.49393	.49576	.49
240	.49940	.50120	.50300	.50479	.50658	.50835	.51012	.51188	.51364	.51
250	$\bar{1}$.51713	$\bar{1}$.51886	$\bar{1}$.52059	$\bar{1}$.52231	$\bar{1}$.52402	$\bar{1}$.52573	$\bar{1}$.52743	$\bar{1}$.52912	$\bar{1}$.53081	$\bar{1}$.53
260	.53416	.53583	.53749	.53914	.54079	.54243	.54407	.54570	.54732	.54
270	.55055	.55216	.55376	.55535	.55694	.55852	.56010	.56167	.56323	.56
280	.56634	.56789	.56944	.57097	.57250	.57403	.57555	.57707	.57858	.58
290	.58158	.58308	.58457	.58605	.58753	.58901	.59048	.59194	.59340	.59
300	$\bar{1}$.59631	$\bar{1}$.59775	$\bar{1}$.59919	$\bar{1}$.60063	$\bar{1}$.60206	$\bar{1}$.60349	$\bar{1}$.60491	$\bar{1}$.60632	$\bar{1}$.60774	$\bar{1}$.60
310	.61055	.61195	.61334	.61473	.61611	.61750	.61887	.62025	.62161	.62
320	.62434	.62569	.62704	.62839	.62973	.63107	.63240	.63373	.63506	.63
330	.63770	.63901	.64032	.64163	.64293	.64423	.64553	.64682	.64810	.64
340	.65067	.65194	.65321	.65448	.65574	.65701	.65826	.65952	.66077	.66

DENSITY OF AIR.

Values of logarithms of $\frac{h}{760}$ for values of h between 350 and 800.

h	Values of log $\frac{h}{760}$.									
	0	1	2	3	4	5	6	7	8	9
350	$\bar{1}$.66325	$\bar{1}$.66449	$\bar{1}$.66573	$\bar{1}$.66696	$\bar{1}$.66819	$\bar{1}$.66941	$\bar{1}$.67064	$\bar{1}$.67185	$\bar{1}$.67307	$\bar{1}$.67428
360	.67549	.67669	.67790	.67909	.68029	.68148	.68267	.68385	.68503	.68621
370	.68739	.68856	.68973	.69090	.69206	.69322	.69437	.69553	.69668	.69783
380	.69897	.70011	.70125	.70239	.70352	.70465	.70577	.70690	.70802	.70914
390	.71025	.71136	.71247	.71358	.71468	.71578	.71688	.71798	.71907	.72016
400	$\bar{1}$.72125	$\bar{1}$.72233	$\bar{1}$.72341	$\bar{1}$.72449	$\bar{1}$.72557	$\bar{1}$.72664	$\bar{1}$.72771	$\bar{1}$.72878	$\bar{1}$.72985	$\bar{1}$.73091
410	.73197	.73303	.73408	.73514	.73619	.73723	.73828	.73932	.74036	.74140
420	.74244	.74347	.74450	.74553	.74655	.74758	.74860	.74961	.75063	.75164
430	.75265	.75366	.75467	.75567	.75668	.75768	.75867	.75967	.76066	.76165
440	.76264	.76362	.76461	.76559	.76657	.76755	.76852	.76949	.77046	.77143
450	$\bar{1}$.77240	$\bar{1}$.77336	$\bar{1}$.77432	$\bar{1}$.77528	$\bar{1}$.77624	$\bar{1}$.77720	$\bar{1}$.77815	$\bar{1}$.77910	$\bar{1}$.78005	$\bar{1}$.78100
460	.78194	.78289	.78383	.78477	.78570	.78664	.78757	.78850	.78943	.79036
470	.79128	.79221	.79313	.79405	.79496	.79588	.79679	.79770	.79861	.79952
480	.80043	.80133	.80223	.80313	.80403	.80493	.80582	.80672	.80761	.80850
490	.80938	.81027	.81115	.81203	.81291	.81379	.81467	.81554	.81642	.81729
500	$\bar{1}$.81816	$\bar{1}$.81902	$\bar{1}$.81989	$\bar{1}$.82075	$\bar{1}$.82162	$\bar{1}$.82248	$\bar{1}$.82334	$\bar{1}$.82419	$\bar{1}$.82505	$\bar{1}$.82590
510	.82676	.82761	.82846	.82930	.83015	.83099	.83184	.83268	.83352	.83435
520	.83519	.83602	.83686	.83769	.83852	.83935	.84017	.84100	.84182	.84264
530	.84346	.84428	.84510	.84591	.84673	.84754	.84835	.84916	.84997	.85076
540	.85158	.85238	.85319	.85399	.85479	.85558	.85638	.85717	.85797	.85876
550	$\bar{1}$.85955	$\bar{1}$.86034	$\bar{1}$.86113	$\bar{1}$.86191	$\bar{1}$.86270	$\bar{1}$.86348	$\bar{1}$.86426	$\bar{1}$.86504	$\bar{1}$.86582	$\bar{1}$.86660
560	.86737	.86815	.86892	.86969	.87047	.87123	.87200	.87277	.87353	.87430
570	.87506	.87282	.87658	.87734	.87810	.87885	.87961	.88036	.88111	.88186
580	.88261	.88336	.88411	.88486	.88560	.88634	.88708	.88782	.88856	.88930
590	.89004	.89077	.89151	.89224	.89297	.89370	.89443	.89516	.89589	.89661
600	$\bar{1}$.89734	$\bar{1}$.89806	$\bar{1}$.89878	$\bar{1}$.89950	$\bar{1}$.90022	$\bar{1}$.90094	$\bar{1}$.90166	$\bar{1}$.90238	$\bar{1}$.90309	$\bar{1}$.90380
610	.90452	.90523	.90594	.90665	.90735	.90806	.90877	.90947	.91017	.91088
620	.91158	.91228	.91298	.91367	.91437	.91507	.91576	.91645	.91715	.91784
630	.91853	.91922	.91990	.92059	.92128	.92196	.92264	.92333	.92401	.92469
640	.92537	.92604	.92672	.92740	.92807	.92875	.92942	.93009	.93076	.93143
650	$\bar{1}$.93210	$\bar{1}$.93277	$\bar{1}$.93343	$\bar{1}$.93410	$\bar{1}$.93476	$\bar{1}$.93543	$\bar{1}$.93609	$\bar{1}$.93675	$\bar{1}$.93741	$\bar{1}$.93807
660	.93873	.93939	.94004	.94070	.94135	.94201	.94266	.94331	.94396	.94461
670	.94526	.94591	.94656	.94720	.94785	.94849	.94913	.94978	.95042	.95106
680	.95170	.95233	.95297	.95361	.95424	.95488	.95551	.95614	.95677	.95741
690	.95804	.95866	.95929	.95992	.96055	.96117	.96180	.96242	.96304	.96366
700	$\bar{1}$.96428	$\bar{1}$.96490	$\bar{1}$.96552	$\bar{1}$.96614	$\bar{1}$.96676	$\bar{1}$.96738	$\bar{1}$.96799	$\bar{1}$.96861	$\bar{1}$.96922	$\bar{1}$.96983
710	.97044	.97106	.97167	.97228	.97288	.97349	.97410	.97471	.97531	.97592
720	.97652	.97712	.97772	.97832	.97892	.97951	.98012	.98072	.98132	.98191
730	.98251	.98310	.98370	.98429	.98488	.98547	.98606	.98665	.98724	.98783
740	.98842	.98900	.98959	.99018	.99076	.99134	.99193	.99251	.99309	.99367
750	$\bar{1}$.99425	$\bar{1}$.99483	$\bar{1}$.99540	$\bar{1}$.99598	$\bar{1}$.99656	$\bar{1}$.99713	$\bar{1}$.99771	$\bar{1}$.99828	$\bar{1}$.99886	$\bar{1}$.99942
760	0.00000	0.00057	0.00114	0.00171	0.00228	0.00285	0.00342	0.00398	0.00455	0.00511
770	.00568	.00624	.00680	.00737	.00793	.00849	.00905	.00961	.01017	.01072
780	.01128	.01184	.01239	.01295	.01350	.01406	.01461	.01516	.01571	.01626
790	.01681	.01736	.01791	.01846	.01901	.01955	.02010	.02064	.02119	.02173

TABLE 146.

VOLUME OF PERFECT GASES.

Values of $1+.00367\,t$.

The quantity $1+.00367\,t$ gives for a perfect gas the volume at $t°$ when the pressure is kept constant, or the pressure at $t°$ when the volume is kept constant, in terms of the volume or the pressure at 0°.

(a) This part of the table gives the values of $1+.00367\,t$ for values of t between 0° and 10° C. by tenths of a degree.

(b) This part gives the values of $1+.00367\,t$ for values of t between −90° and +1990° C. by 10° steps.

These two parts serve to give any intermediate value to one tenth of a degree by a simple computation as follows: — In the (*b*) table find the number corresponding to the nearest lower temperature, and to this number add the decimal part of the number in the (*a*) table which corresponds to the difference between the nearest temperature in the (*b*) table and the actual temperature. For example, let the temperature be 682°.2:

We have for 680 in table (*b*) the number	3.49560
And for 2.2 in table (*a*) the decimal	.00807
Hence the number for 682.2 is	3.50367

(c) This part gives the logarithms of $1+.00367\,t$ for values of t between −49° and +399° C. by degrees.

(d) This part gives the logarithms of $1+.00367\,t$ for values of t between 400° and 1990° C. by 10° steps.

(a) Values of $1+.00367\,t$ for Values of t between 0° and 10° C. by Tenths of a Degree.

t	0.0	0.1	0.2	0.3	0.4
0	1.00000	1.00037	1.00073	1.00110	1.00147
1	.00367	.00404	.00440	.00477	.00514
2	.00734	.00771	.00807	.00844	.00881
3	.01101	.01138	.01174	.01211	.01248
4	.01468	.01505	.01541	.01578	.01615
5	1.01835	1.01872	1.01908	1.01945	1.01982
6	.02202	.02239	.02275	.02312	.02349
7	.02569	.02606	.02642	.02679	.02716
8	.02936	.02973	.03009	.03046	.03083
9	.03303	.03340	.03376	.03413	.03450
t	0.5	0.6	0.7	0.8	0.9
0	1.00184	1.00220	1.00257	1.00294	1.00330
1	.00550	.00587	.00624	.00661	.00697
2	.00918	.00954	.00991	.01028	.01064
3	.01284	.01321	.01358	.01395	.01431
4	.01652	.01688	.01725	.01762	.01798
5	1.02018	1.02055	1.02092	1.02129	1.02165
6	.02386	.02422	.02459	.02496	.02532
7	.02752	.02789	.02826	.02863	.02899
8	.03120	.03156	.03193	.03290	.03266
9	.03486	.03523	.03560	.03597	.03633

VOLUME OF PERFECT GASES.

(b) Values of $1 + .00367t$ for Values of t between $-90°$ and $+1990°$ C. by $10°$ Steps.

t	00	10	20	30	40
—000	1.00000	0.96330	0.92660	0.88990	0.85320
+000	1.00000	1.03670	1.07340	1.11010	1.14680
100	1.36700	1.40370	1.44040	1.47710	1.51380
200	1.73400	1.77070	1.80740	1.84410	1.88080
300	2.10100	2.13770	2.17440	2.21110	2.24780
400	2.46800	2.50470	2.54140	2.57810	2.61480
500	2.83500	2.87170	2.90840	2.94510	2.98180
600	3.20200	3.23870	3.27540	3.31210	3.34880
700	3.56900	3.60570	3.64240	3.67910	3.71580
800	3.93600	3.97270	4.00940	4.04610	4.08280
900	4.30300	4.33970	4.37640	4.41310	4.44980
1000	4.67000	4.70670	4.74340	4.78010	4.81680
1100	5.03700	5.07370	5.11040	5.14710	5.18380
1200	5.40400	5.44070	5.47740	5.51410	5.55080
1300	5.77100	5.80770	5.84440	5.88110	5.91780
1400	6.13800	6.17470	6.21140	6.24810	6.28480
1500	6.50500	6.54170	6.57840	6.61510	6.65180
1600	6.87200	6.90870	6.94540	6.98210	7.01880
1700	7.23900	7.27570	7.31240	7.34910	7.38580
1800	7.60600	7.64270	7.67940	7.71610	7.75280
1900	7.97300	8.00970	8.04640	8.08310	8.11980
2000	8.34000	8.37670	8.41340	8.45010	8.48680

t	50	60	70	80	90
—000	0.81650	0.77980	0.74310	0.70640	0.66970
+000	1.18350	1.22020	1.25690	1.29360	1.33030
100	1.55050	1.58720	1.62390	1.66060	1.69730
200	1.91750	1.95420	1.99090	2.02760	2.06430
300	2.28450	2.32120	2.35790	2.39460	2.43130
400	2.65150	2.68820	2.72490	2.76160	2.79830
500	3.01850	3.05520	3.09190	3.12860	3.16530
600	3.38550	3.42220	3.45890	3.49560	3.53230
700	3.75250	3.78920	3.82590	3.86260	3.89930
800	4.11950	4.15620	4.19290	4.22960	4.26630
900	4.48650	4.52320	4.55990	4.59660	4.63330
1000	4.85350	4.89020	4.92690	4.96360	5.00030
1100	5.22050	5.25720	5.29390	5.33060	5.36730
1200	5.58750	5.62420	5.66090	5.69760	5.73430
1300	5.95450	5.99120	6.02790	6.06460	6.10130
1400	6.32150	6.35820	6.39490	6.43160	6.46830
1500	6.68850	6.72520	6.76190	6.79860	6.83530
1600	7.05550	7.09220	7.12890	7.16560	7.20230
1700	7.42250	7.45920	7.49590	7.53260	7.56930
1800	7.78950	7.82620	7.86290	7.89960	7.93630
1900	8.15650	8.19320	8.22990	8.26660	8.30330
2000	8.52350	8.56020	8.59690	8.63360	8.67030

(c) Logarithms of $1+.00367\,t$ for Values

t	0	1	2	3	4	Mean diff. per degree.
−40	$\bar{1}.931051$	$\bar{1}.929179$	$\bar{1}.927299$	$\bar{1}.925410$	$\bar{1}.923513$	1884
−30	.949341	.947546	.945744	.943934	.942117	1805
−20	.966892	.965169	.963438	.961701	.959957	1733
−10	.983762	.982104	.980440	.978769	.977092	1667
−0	0.000000	.998403	.996801	.995192	.993577	1605
+0	0.000000	0.001591	0.003176	0.004755	0.006329	1582
10	.015653	.017188	.018717	.020241	.021760	1526
20	.030762	.032244	.033721	.035193	.036661	1474
30	.045362	.046796	.048224	.049648	.051068	1426
40	.059488	.060875	.062259	.063637	.065012	1381
50	0.073168	0.074513	0.075853	0.077190	0.078522	1335
60	.086431	.087735	.089036	.090332	.091624	1299
70	.099301	.100567	.101829	.103088	.104344	1259
80	.111800	.113030	.114257	.115481	.116701	1226
90	.123950	.125146	.126339	.127529	.128716	1191
100	0.135768	0.136933	0.138094	0.139252	0.140408	1158
110	.147274	.248408	.149539	.150667	.151793	1129
120	.158483	.159588	.160691	.161790	.162887	1101
130	.169410	.170488	.171563	.172635	.173705	1074
140	.180068	.181120	.182169	.183216	.184260	1048
150	0.190472	0.191498	0.192523	0.193545	0.194564	1023
160	.200632	.201635	.202635	.203634	.204630	1000
170	.210559	.211540	.212518	.213494	.214468	976
180	.220265	.221224	.222180	.223135	.224087	956
190	.229759	.230697	.231633	.232567	.233499	935
200	0.239049	0.239967	0.240884	0.241798	0.242710	916
210	.248145	.249044	.249942	.250837	.251731	897
220	.257054	.257935	.258814	.259692	.260567	878
230	.265784	.266648	.267510	.268370	.269228	861
240	.274343	.275189	.276034	.276877	.277719	844
250	0.282735	0.283566	0.284395	0.285222	0.286048	828
260	.290969	.291784	.292597	.293409	.294219	813
270	.299049	.299849	.300648	.301445	.302240	798
280	.306982	.307768	.308552	.309334	.310115	784
290	.314773	.315544	.316314	.317083	.317850	769
300	0.322426	0.323184	0.323941	0.324696	0.325450	756
310	.329947	.330692	.331435	.332178	.332919	743
320	.337339	.338072	.338803	.339533	.340262	730
330	.344608	.345329	.345048	.346766	.347482	719
340	.351758	.352466	.353174	.353880	.354585	707
350	0.358791	0.359488	0.360184	0.360879	0.361573	696
360	.365713	.366399	.367084	.367768	.368451	684
370	.372525	.373201	.373875	.374549	.375221	674
380	.379233	.379898	.380562	.381225	.381887	664
390	.385439	.386494	.387148	.387801	.388453	654

PERFECT GASES.

of t between $-49°$ and $+399°$ C. by Degrees.

t	5	6	7	8	9	Mean diff. per degree.
−40	$\bar{1}$.921608	$\bar{1}$.919695	$\bar{1}$.917773	$\bar{1}$.915843	$\bar{1}$.913904	1926
−30	.940292	.938460	.936619	.934771	.932915	1845
−20	.958205	.956447	.954681	.952909	.951129	1771
−10	.975409	.973719	.972022	.970319	.968609	1699
−0	.991957	.990330	.988697	.987058	.985413	1636
+0	0.007897	0.009459	0.011016	0.012567	0.014113	1554
10	.023273	.024781	.026284	.027782	.029274	1500
20	.038123	.039581	.041034	.042481	.043924	1450
30	.052482	.053893	.055298	.056699	.058096	1402
40	.066382	.067748	.069109	.070466	.071819	1359
50	0.079847	0.081174	0.082495	0.083811	0.085123	1315
60	.092914	.094198	.095486	.096765	.098031	1281
70	.105595	.106843	.108088	.109329	.110566	1243
80	.117917	.119130	.120340	.121547	.122750	1210
90	.129899	.131079	.132256	.133430	.134601	1175
100	0.141559	0.142708	0.143854	0.144997	0.146137	1144
110	.152915	.154034	.155151	.156264	.157375	1115
120	.163981	.164072	.166161	.167246	.168330	1087
130	.174772	.175836	.176898	.177958	.179014	1060
140	.185301	.186340	.187377	.188411	.189443	1035
150	0.195581	0.196596	0.197608	0.198619	0.199626	1011
160	.205624	.206615	.207605	.208592	.209577	988
170	.215439	.216409	.217376	.218341	.219304	966
180	.225038	.225986	.226932	.227876	.228819	946
190	.234429	.235357	.236283	.237207	.238129	925
200	0.243621	0.244529	0.245436	0.246341	0.247244	906
210	.252623	.253512	.254400	.255287	.256172	887
220	.261441	.262313	.263184	.264052	.264919	870
230	.270085	.270940	.271793	.272644	.273494	853
240	.278559	.279398	.280234	.281070	.281903	836
250	0.286872	0.287694	0.288515	0.289326	0.290153	820
260	.295028	.295835	.296640	.297445	.298248	805
270	.303034	.303827	.304618	.305407	.306196	790
280	.310895	.311673	.312450	.313226	.314000	776
290	.318616	.319381	.320144	.320906	.321667	763
300	0.326203	0.326954	0.327704	0.328453	0.329201	750
310	.333659	.334397	.335135	.335871	.336606	737
320	.340989	.341715	.342441	.343164	.343887	724
330	.348198	.348912	.349624	.350337	.351048	713
340	.355289	.355991	.356693	.357394	.358093	701
350	0.362266	0.362957	0.363648	0.364337	0.365025	690
360	.369132	.369813	.370493	.371171	.371849	678
370	.375892	.376562	.377232	.377900	.378567	668
380	.382548	.383208	.383868	.384525	.385183	658
390	.389104	.389754	.390403	.391052	.391699	648

VOLUME OF PERFECT GASES.

(d) Logarithms of $1+.00367t$ for Values of t between 400° and 1990° C. by 10° Steps.

t	00	10	20	30	40
400	0.392345	0.398756	0.405073	0.411300	0.417439
500	0.452553	0.458139	0.463654	0.469100	0.474479
600	.505421	.510371	.515264	.520103	.524889
700	.552547	.556990	.561388	.565742	.570052
800	.595055	.599086	.603079	.607037	.610958
900	.633771	.637460	.641117	.644744	.648341
1000	0.669317	0.672717	0.676090	0.679437	0.682759
1100	.702172	.705325	.708455	.711563	.714648
1200	.732715	.735655	.738575	.741475	.744356
1300	.761251	.764004	.766740	.769459	.772160
1400	.788027	.790616	.793190	.795748	.798292
1500	0.813247	0.815691	0.818120	0.820536	0.822939
1600	.837083	.839396	.841697	.843986	.846263
1700	.859679	.861875	.864060	.866234	.868398
1800	.881156	.883247	.885327	.887398	.889459
1900	.901622	.903616	.905602	.907578	.909545

t	50	60	70	80	90
400	0.423492	0.429462	0.435351	0.441161	0.446894
500	0.479791	0.485040	0.490225	0.495350	0.500415
600	.529623	.534305	.538938	.543522	.548058
700	.574321	.578548	.582734	.586880	.590987
800	.614845	.618696	.622515	.626299	.630051
900	.651908	.655446	.658955	.662437	.665890
1000	0.686055	0.689327	0.692574	0.695797	0.698996
1100	.717712	.720755	.723776	.726776	.729756
1200	.747218	.750061	.752886	.755692	.758480
1300	.774845	.777514	.780166	.782802	.785422
1400	.800820	.803334	.805834	.808319	.810790
1500	0.825329	0.827705	0.830069	0.832420	0.834758
1600	.848528	.850781	.853023	.855253	.857471
1700	.870550	.872692	.874824	.876945	.879056
1800	.891510	.893551	.895583	.897605	.899618
1900	.911504	.913454	.915395	.917327	.919251

DETERMINATION OF HEIGHTS BY THE BAROMETER.

Formula of Babinet: $Z = C \frac{B_0 - B}{B_0 + B}$

C (in feet) $= 52494 \left[1 + \frac{t_0 + t - 64}{900}\right]$ English measures.

C (in metres) $= 16000 \left[1 + \frac{2(t_0 + t)}{1000}\right]$ metric measures.

In which Z = difference of height of two stations in feet or metres.

B_0, B = barometric readings at the lower and upper stations respectively, corrected for all sources of instrumental error.

t_0, t = air temperatures at the lower and upper stations respectively.

Values of C.

ENGLISH MEASURES.			METRIC MEASURES.		
$\frac{1}{2}(t_0+t)$.	C	Log C	$\frac{1}{2}(t_0+t)$.	C	Log C
Fahr.	Feet.		Cent.	Metres.	
10°	49928	4.69834	**−10°**	15360	4.18639
15	50511	.70339	−8	15488	.19000
			−6	15616	.19357
20	51094	4.70837	−4	15744	.19712
25	51677	.71330	−2	15872	.20063
30	52261	4.71818	**0**	16000	4.20412
35	52844	.72300	+ 2	16128	.20758
			4	16256	.21101
40	53428	4.72777	6	16384	.21442
45	54011	.73248	8	16512	.21780
50	54595	4.73715	**10**	16640	4.22115
55	55178	.74177	12	16768	.22448
			14	16896	.22778
60	55761	4.74633	16	17024	.23106
65	56344	.75085	18	17152	.23431
70	56927	4.75532	**20**	17280	4.23754
75	57511	.75975	22	17408	.24075
			24	17536	.24393
80	58094	4.76413	26	17664	.24709
85	58677	.76847	28	17792	.25022
90	59260	4.77276	**30**	17920	4.25334
95	59844	.77702	32	18048	.25643
			34	18176	.25950
100	60427	4.78123	36	18304	.26255

Barometric pressures corresponding to di
This table is useful when a boiling-point apparatus i

(a) Common Measure.*

Temp. ° F.	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
185	17.06	17.09	17.13	17.17	17.20	17.24	17.28	17.32	17.35	17.
186	17.42	17.47	17.51	17.54	17.58	17.62	17.66	17.70	17.74	17.
187	17.81	17.85	17.89	17.93	17.97	18.01	18.05	18.08	18.12	18.
188	18.20	18.24	18.28	18.32	18.36	18.40	18.44	18.48	18.52	18.
189	18.60	18.64	18.68	18.72	18.76	18.80	18.84	18.88	18.92	18.
190	19.00	19.04	19.08	19.12	19.16	19.21	19.25	19.29	19.33	19.
191	19.41	19.45	19.49	19.54	19.58	19.62	19.66	19.70	19.75	19.
192	19.83	19.87	19.91	19.96	20.00	20.04	20.08	20.13	20.17	20.
193	20.26	20.30	20.34	20.38	20.43	20.47	20.51	20.56	20.60	20.
194	20.68	20.73	20.78	20.82	20.86	20.91	20.95	20.99	21.04	21.
195	21.13	21.17	21.22	21.26	21.31	21.35	21.40	21.44	21.48	21.
196	21.58	21.62	21.67	21.71	21.76	21.80	21.85	21.90	21.94	21.
197	22.03	22.08	22.13	22.17	22.22	22.27	22.31	22.36	22.41	22.
198	22.50	22.55	22.59	22.64	22.69	22.73	22.78	22.83	22.88	22.
199	22.97	23.02	23.07	23.12	23.16	23.21	23.26	23.31	23.36	23.
200	23.45	23.50	23.55	23.60	23.65	23.70	23.75	23.79	23.84	23.
201	23.94	23.99	24.04	24.09	24.14	24.19	24.24	24.29	24.34	24.
202	24.44	24.49	24.54	24.59	24.64	24.69	24.74	24.79	24.85	24.
203	24.95	25.00	25.05	25.10	25.15	25.20	25.26	25.31	25.36	25.
204	25.46	25.52	25.57	25.62	25.67	25.72	25.78	25.83	25.88	25.
205	25.99	26.04	26.09	26.15	26.20	26.25	26.31	26.36	26.41	26.
206	26.52	26.58	26.63	26.68	26.74	26.79	26.85	26.90	26.96	27.
207	27.06	27.12	27.17	27.23	27.28	27.34	27.39	27.45	27.51	27.
208	27.62	27.67	27.73	27.78	27.84	27.90	27.95	28.01	28.07	28.
209	28.18	28.24	28.29	28.35	28.41	28.46	28.52	28.58	28.63	28.
210	28.75	28.81	28.87	28.92	28.98	29.04	29.10	29.16	29.21	29.
211	29.33	29.39	29.45	29.51	29.57	29.63	29.68	29.74	29.80	29.
212	29.92	29.98	30.04	30.10	30.16	30.22	30.28	30.34	30.40	30.

* Pressures in inches of mercury.

PRESSURES.

temperatures of the boiling-point of water.
in place of the barometer for the determination of heights.

(b) **Metric Measure.***

Temp. °C.	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
80°	354.9	356.3	357.8	359.2	360.7	362.1	363.6	365.1	366.5	368.0
81	369.5	371.0	372.5	374.0	375.5	377.0	378.5	380.0	381.6	383.1
82	384.6	386.2	387.7	389.3	390.8	392.4	394.0	395.5	397.1	398.7
83	400.3	401.9	403.5	405.1	406.7	408.3	409.9	411.6	413.2	414.8
84	416.5	418.1	419.8	421.4	423.1	424.8	426.4	428.1	429.8	431.5
85	433.2	434.9	436.6	438.3	440.0	441.8	443.5	445.2	447.0	448.7
86	450.5	452.2	454.0	455.8	457.5	459.3	461.1	462.9	464.7	466.5
87	468.3	470.1	472.0	473.8	475.6	477.5	479.3	481.2	483.0	484.9
88	486.8	488.6	490.5	492.4	494.3	496.2	498.1	500.0	501.9	503.9
89	505.8	507.7	509.7	511.6	513.6	515.6	517.5	519.4	521.5	523.5
90	525.5	527.5	529.5	531.5	533.5	535.5	537.6	539.6	541.6	543.7
91	545.8	547.8	549.9	552.0	554.1	556.2	558.3	560.4	562.5	564.6
92	566.7	568.8	571.0	573.1	575.3	577.4	579.6	581.8	584.0	586.1
93	588.3	590.5	592.7	595.0	597.2	599.4	601.6	603.9	606.1	608.4
94	610.6	612.9	615.2	617.5	619.8	622.1	624.4	626.7	629.0	631.3
95	633.7	636.0	638.4	640.7	643.1	645.4	647.8	650.2	652.6	655.0
96	657.4	659.8	662.3	664.7	667.1	669.5	672.0	674.5	676.9	679.4
97	681.9	684.4	686.9	689.4	691.9	694.5	696.9	699.5	702.0	704.6
98	707.1	709.7	712.3	714.9	717.4	720.0	722.7	725.3	727.9	730.5
99	733.2	735.8	738.5	741.1	743.8	746.5	749.2	751.9	754.6	757.3
100	760.0	762.7	765.5	768.2	771.0	773.7	776.5	779.3	782.1	784.9

* Pressures in millimetres of mercury.

STANDARD WAVE-LENGTHS.

TABLE 149.—Standard Iron Lines. Fabry-Buisson Values.

Referred to the Cd line, λ=6438.4722.
Source: electric arc; current: 3–5 amperes; voltage: generally 110 volts.

Wave-length.	*	Wave-length.	*	Wave-length.	*	Wave-length.	*
2373.737	–	3513.820	—.145	4592.658	—.182	5455.616	—.218
2413.310	–	3556.879	—.157	4602.944	—.182	5497.521	—.214
2435.159 Si	–	3606.681	—.157	4647.437	—.180	5506.783	—.217
2506.904 Si	–	3640.391	—.144	4678.855	—.172	5535.418	—.226
2528.516	–	3677.628	—.136	4707.287	—.170	5569.632	—.216
2562.541	–	3724.379	—.147	4736.785	—.178	5586.770	—.221
2588.016	–	3753.615	—.117	4754.046 Mn	—.179	5615.658	—.219
2628.296	–	3805.346	—.140	4789.657	—.192	5658.835	—.217
2679.065	–	3843.261	—.143	4823.521 Mn	—.176	5709.396	—.205
2714.419	–	3865.526	—.148	4859.756	—.172	5760.843 Ni	—.209
2739.550	–	3906.481	—.147	4878.226	—.181	5763.013	—.205
2778.225	–	3935.818	—.147	4903.324	—.178	5805.211 Ni	—.230
2813.290	–	3977.745	—.146	4919.006	—.168	5857.760 Ni	—.216
2851.800	–	4021.872	—.146	4966.104	—.166	5892.882 Ni	—.215
2874.176	–	4076.641	—.151	5001.880	—.164	5934.683	—.198
2912.157	–	4118.552	—.156	5012.072	—.180	5952.739	—.204
2941.347	–	4134.685	—.155	5049.827	—.181	6003.039	—.200
2987.293	—.146	4147.677	—.159	5083.343	—.175	6027.059	—.215
3030.152	—.109	4191.441	—.154	5110.415	—.159	6065.493	—.216
3075.725	—.115	4233.615	—.157	5127.364	—.169	6137.700	—.215
3125.661	—.118	4282.407	—.158	5167.492	—.186	6191.569	—.210
3175.447	—.115	4315.089	—.173	5192.362	—.161	6230.732	—.211
3225.790	—.129	4352.741	—.167	5232.958	—.164	6265.147	—.201
3271.003	—.126	4375.935	—.172	5266.568	—.169	6318.029	—.210
3323.739	—.142	4427.314	—.168	5302.316	—.164	6335.343	—.211
3370.789	—.144	4466.554	—.173	5324.196	—.177	6393.612	—.208
3399.337	—.152	4494.572	—.166	5371.498	—.236	6430.859	—.207
3445.155	—.105	4531.155	—.172	5405.780	—.209	6494.994	—.219
3485.344	—.149	4547.854	—.170	5434.530	—.210		

Taken from Fabry and Buisson, Astrophysical Journal, 28, 1908.

* These columns give the differences: Fabry-Buisson minus the corresponding iron line in Rowland's Preliminary Table of Solar Spectrum Wave-lengths.

TABLE 150.—Absolute Wave-length of Red Cadmium Line in Air, 760 mm. Pressure, 15° C.

6438.4722.....Michelsen.
6438.4696.....Fabry and Perot.

For arc and spark lines of titanium, manganese, and vanadium (on above system of wave-lengths), see Kilby, Astrophysical Journal, 30, 1909.

TABLE 151.—Some of the Stronger Lines of Some of the Elements.

Barium .	5535.7	Helium .	5875.8	Magnesium	5167.5	Sodium .	5890.2
Cæsium .	4555.4	" . .	5876.2	" . .	5172.9	" . .	5896.2
" . .	4593.3	Hydrogen	4101.8	" . .	5183.8	Strontium	4607.5
Calcium .	5589.0	" . .	4340.7	Mercury . .	5461.0	" . .	5481.2
Cadmium	4799.9	" . .	4861.5	Potassium .	7668.5	" . .	6408.6
" . .	5085.8	" . .	6563.0	" . .	7701.9	Thallium .	5350.6
" . .	6438.5	Lithium .	6708.2	Rubidium .	6298.7		

STANDARD SOLAR WAVE-LENGTHS. ROWLAND'S VALUES.

Wave-lengths are in Ångström units (10^{-7} mm.), in air at 20° C and 76 cm. of mercury pressure. The intensities run from 1, just clearly visible on the map, to 1000 for the H and K lines; below 1 in order of faintness to 0000 as the lines are more and more difficult to see. This table contains only the lines above 5.

N indicates a line not clearly defined, probably an undissolved multiple line; s, a faded appearing line; d, a double. In the "substance" column, where two or more elements are given, the line is compound; the order in which they are given indicates the portion of the line due to each element; when the solar line is too strong to be due wholly to the element given, it is represented, **–Fe**, for example; when commas separate the elements instead of a dash, the metallic lines coincide with the same part of the solar line, **Fe, Cr**, for example.

Capital letters next the wave-length numbers are the ordinary designations of the lines. **A** indicates atmospheric lines, (wv), due to water vapor, (O), due to Oxygen.

Wave-length.	Substance.	Intensity.	Wave-length.	Substance.	Intensity.	Wave-length.	Substance.	Intensity.
3037.510s	Fe	10 N	3372.947	Ti–Pd	10 d?	3533.345	Fe	6
3047.725s	Fe	20 N	3380.722	Ni	6 N	3536.709	Fe	7
3053.530s	–	7 d?	3414.911	Ni	15	3541.237	Fe	7
3054.429	Mn, Ni	10	3423.848	Ni	7	3542.232	Fe	6
3057.552s	Ti, Fe	20	3433.715	Ni, Cr	8 d?	3555.079	Fe	9
3059.212s	Fe	20	3440.762s } O	Fe	20	3558.672s	Fe	8
3067.369s	Fe	8	3441.155s }	Fe	15	3565.535s	Fe	12
3073.091	Ti, –	6 Nd?	3442.118	Mn	6	3566.522	Ni	10
3078.769s	Ti, –	8 d?	3444.020s	Fe	8 N	3570.273s	Fe	20
3088.145s	Ti	7 d?	3446.406	Ni	15	3572.014	Ni	6
3134.230s	Ni, Fe	8	3449.583	Co	6 d?	3572.712	Se, –	6
3188.656	–, Fe	6 d?	3453.039	Ni	6 d?	3578.832	Cr	10
3236.703s	Ti	7 N	3458.601	Ni	8	3581.349s	Fe	30
3239.170	Ti	7	3461.801	Ni	8	3584.800	Fe	6
3242.125	Ti, –	8	3462.950	Co	6	3585.105	Fe	6
3243.189	–, Ni	6	3466.015s	Fe	6	3585.479	Fe	7
3247.688s	Cu	10	3475.594s	Fe	10	3585.859	Fe	6
3256.021	Fe?	6	3476.849s	Fe	8	3587.130	Fe	8
3267.834s	V	6	3483.923	Ni	6 d?	3587.370	Co	7
3271.129	Fe	6	3485.493	Fe Co	6	3588.084	Ni	6
3271.791	Ti, Fe	6 d?	3490.733s	Fe	10 N	3593.636	Cr	9
3274.096s	Cu	10	3493.114	Ni	10 N	3594.784	Fe	6
3277.482	Co–Fe	7 d?	3497.982s	Fe	8	3597.854	Ni	8
3286.898	Fe	7 N	3500.996s	Ni	6 d?	3605.479s	Cr	7
3295.951s	Fe, Mn	6	3510.466	Ni	8	3606.838s	Fe	6
3302.510s	Na	6	3512.785	Co	6	3609.008s	Fe	20
3315.807	Ni	7 d?	3513.965s	Fe	7	3612.882	Ni	6 d?
3318.160s	Ti	6	3515.206	Ni	12	3617.934s	Fe	6
3320.391	Ni	7	3519.904	N	7	3618.919s	Fe	20
3336.820	Mg	8 N	3521.410s	Fe	8	3619.539	Ni	8
3349.597	Ti	7	3524.677	Ni	20	3621.612s	Fe	6
3361.327	Ti	8	3526.183	Fe	6	3622.147s	Fe	6
3365.908	Ni	6	3526.988	Co	6	3631.605s	Fe	15
3366.311	Ti, Ni	6 d?	3529.964	Fe–Co	6	3640.535s	Cr–Fe	6
3369.713	Fe, Ni	6	3533.156	Fe	6	3642.820	Ti	7

Corrections to reduce Rowland's wave-lengths to Fabry and Buisson's system (the accepted standard, 1908). Temperature 15° C. pressure 760 mm.

The differences "(Fabry-Buisson-arc-iron) — (Rowland-solar-iron)" lines were plotted, a smooth curve drawn, and the following values obtained:

Wave-length	3000.	3100.	3200.	3300.	3400.	3500.	3600.	3700.
Correction	—.106	—.115	—.124	—.137	—.148	—.154	—.155	—.140

H. A. Rowland, "A preliminary table of solar-spectrum wave-lengths," Astrophysical Journal, 1–6, 1895–1897.

STANDARD SOLAR WAVE-LENGTHS. ROWLAND'S VALUES.

Wave-length.	Substance.	Intensity.	Wave-length.	Substance.	Intensity.	Wave-length.	Substance.	Intensity.
3647.988s	Fe	12	3826.027s	Fe	20	4045.975s	Fe	30
3651.247	Fe,-	6	3827.980	Fe	80	4055.701s	Mn	6
3651.614	Fe	7	3829.501s	Mg	10	4057.668	–	7
3676.457	Fe, Cr	6	3831.837	Ni	6	4063.759s	Fe	20
3680.069s	Fe	9	3832.450s	Mg	15	4068.137	Fe–Mn	6
3684.258s	Fe	7d?	3834.364	Fe	10	4071.908s	Fe	15
3685.339	Ti	10d?	3838.435s	Mg–C	25	4077.885s	Sr	8
3686.141	Ti–Fe	6	3840.580s	Fe–C	8	4102.000Hδ	H, In	40N
3687.610s	Fe	6	3841.195	Fe–Mn	10	4121.477s	Cr–Co	6d?
3689.614	Fe	6	3845.606	C–Co	8d?	4128.251	Ce–V,-	6d
3701.234	Fe	8	3850.118	Fe–Cr	10	4132.235	Fe–Co	10
3705.708s	Fe	9	3856.524s	Fe	8	4137.156	Fe	6
3706.175	Ca, Mn	6d?	3857.805	Cr–C	6d?	4140.089	Fe	6
3709.389s	Fe	8	3858.442	Ni	7	4144.038	Fe	15
3716.591s	Fe	7	3860.055s	Fe–C	20	4167.438	–	8
3720.084s	Fe	40	3865.674	Fe–C	7	4187.204	Fe	6
3722.692s	Ni	10	3872.639	Fe	6	4191.595	Fe	6
3724.526	Fe	6	3878.152	Fe–C	8	4202.198s	Fe	8
3732.545s	Co–Fe	6	3878.720	Fe	7Nd?	4226.904sg	Ca	20 d?
3733.469s	Fe–	7d?	3886.434s	Fe	15	4233.772	Fe	6
3735.014s	Fe	40	3887.196	Fe	7	4236.112	Fe	8
3737.281s	Fe	30	3894.211	–	8d	4250.287s	Fe	8
3738.466	–	6	3895.803	Fe	7	4250.945s	Fe	8
3743.508	Fe–Ti	6	3899.850	Fe	8	4254.505s	Cr	8
3745.717s	Fe	8	3903.090	Cr, Fe, Mo	10	4260.640s	Fe	10
3746.058s	Fe	6	3904.023	–	8d	4271.934s	Fe	15
3748.408s	Fe	10	3905.660s	Si	12	4274.958s	Cr	7d?
3749.631s	Fe	20	3906.628	Fe	10	4308.081sG	Fe	6
3753.732	Fe–Ti	6d?	3920.410	Fe	10	4325.939s	Fe	8
3758.375s	Fe	15	3923.054	Fe	12d?	4340.634Hγ	H	20N
3759.447	Ti	12d?	3928.075s	Fe	8	4376.107s	Fe	6
3760.196	Fe	5	3930.450	Fe	8	4383.720s	Fe	15
3761.464	Ti	7	3933.523	–	8N	4404.927s	Fe	10
3763.945s	Fe	10	3933.825sK	Ca	1000	4415.293s	Fe	8
3765.689	Fe	6	3934.108	Co, V–Cr	8N	4442.510	Fe	6
3767.341s	Fe	8	3944.160s	Al	15	4447.892s	Fe	6
3775.717	Ni	7	3956.819	Fe	6	4494.738s	Fe	6
3783.674s	Ni	6	3957.177s	Fe–Ca	7d?	4528.798	Fe	8
3788.046s	Fe	9	3961.674s	Al	20	4534.139	Ti–Co	6
3795.147s	Fe	8	3968.350	–, Zr	6N	4549.808	Ti–Co	6d?
3798.655s	Fe	6	3968.625sH	Ca	700	4554.211s	Ba	8
3799.693s	Fe	7	3968.886	–	6N	4572.156s	Ti–	6
3805.486s	Fe	6	3969.413	Fe	10	4603.126	Fe	6
3806.865	Mn–Fe	8d?	3974.904	Co–Fe	6d?	4629.521s	Ti–Co	6
3807.293	Ni	6	3977.891s	Fe	6	4679.027s	Fe	6
3807.681	V–Fe	6	3986.903s	–	6	4703.177s	Mg	10
3814.698	–	8	4005.408	Fe	7	4714.599s	Ni	6
3815.987s	Fe	15	4030.918s	Mn	10d?	4736.963	Fe	6
3820.586sL	Fe–C	25	4033.224s	Mn	8d?	4754.225s	Mn	7
3824.591	Fe	6	4034.644s	Mn	6d	4783.613s	Mn	6

Corrections to reduce Rowland's wave-lengths to Fabry and Buisson's system (the accepted standard, 1908). Temperature 15° C, pressure 760 mm.

Wave-length	3600.	3700.	3800.	3900.	4000.	4100.	4200.	4300.	4400.	4500.	4600.	4700.	4800.
Correction	—.155	—.140	—.141	—.144	—.148	—.152	—.156	—.161	—.167	—.172	—.176	—.179	—.179.

STANDARD SOLAR WAVE-LENGTHS. ROWLAND'S VALUES.

Wave-length.	Substance.	Intensity.	Wave-length.	Substance.	Intensity.	Wave-length.	Substance.	Intensity.
4861.527sF	H	30	5948.765s	Si	6	6563.045sC	H	40
4890.948s	Fe	6	5985.040s	Fe	6	6593.161s	Fe	6
4891.683	Fe	8	6003.239s	Fe	6	6867.457sB	A(O)	6d?
4919.174s	Fe	6	6008.785s	Fe	6	6868.336 }s	A(O)	6
4920.685	Fe	10	6013.715s	Mn	6	6868.478 }	A(O)	6
4957.785s	Fe	8	6016.861s	Mn	6	6869.142s	A(O)	7
5050.008s	Fe	6	6022.016s	Mn	6	6869.353s	A(O)	6
5167.497sb$_4$	Mg	15	6024.281s	Fe	7	6870.116 }s	A(O)	7 }d
5171.778s	Fe	6	6065.709s	Fe	7	6870.249 }	A(O)	7 }
5172.856sb$_2$	Mg	20	6102.392s	Fe	6	6871.180s	A(O)	8
5183.791sb$_1$	Mg	30	6102.937s	Ca	9	6871.532s	A(O)	10
5233.122s	Fe	7	6108.334s	Ni	6	6872.486s	A(O)	11
5266.738s	Fe	6	6122.434s	Ca	10	6873.080s	A(O)	12
5269.723sE	Fe	8d?	6136.829s	Fe	8	6874.037s	A(O)	12
5283.802s	Fe	6	6137.915	Fe	7	6874.899s	A(O)	13
5324.373s	Fe	7	6141.938s	Fe, Ba	7	6875.830s	A(O)	13
5328.236	Fe	8d?	6155.350	–	7	6876.958s	A(O)	13
5340.121	Fe	6	6162.390s	Ca	15	6877.882s	A(O)	12
5341.213	Fe	7	6169.249s	Ca	6	6879.288s	A(O)	12
5367.669s	Fe	6	6169.778s	Ca	7	6880.172s	A(O)	6
5370.166s	Fe	6	6170.730	Fe–Ni	6	6884.076s	A(O)	10
5383.578s	Fe	6	6191.393s	Ni	6	6886.000s	A(O)	11
5397.344s	Fe	7d?	6191.779s	Fe	9	6886.990s	A(O)	12
5405.989s	Fe	6	6200.527s	Fe	6	6889.192s	A(O)	13
5424.290s	Fe	6	6213.644s	Fe	6	6890.151s	A(O)	14
5429.911	Fe	6d?	6219.494s	Fe	6	6892.618s	A(O)	14
5447.130s	Fe	6d?	6230.943s	V–Fe	8	6893.560s	A(O)	15
5528.641s	Mg	8	6246.535s	Fe	8	6896.289s	A(O)	14
5569.848	Fe	6	6252.773s	–Fe	7	6897.208s	A(O)	15
5573.075	Fe	6	6256.572s	Ni–Fe	6	6900.199s	A(O)	14
5586.991	Fe	7	6301.718	Fe	7	6901.117s	A(O)	15
5588.985s	Ca	6	6318.239	Fe	6	6904.362s	A(O)	14
5615.877s	Fe	6	6335.554	Fe	6	6905.271s	A(O)	14
5688.436s	Na	6	6337.048	Fe	7	6908.783s	A(O)	13
5711.313s	Mg	6	6358.898	Fe	6	6909.676s	A(O)	13
5763.218s	Fe	6	6393.820s	Fe	7	6913.448s	A(O)	11
5857.674s	Ca	8	6400.217s	Fe	8	6914.337s	A(O)	11
5862.582s	Fe	6	6411.865s	Fe	7	6918.370s	A(O)	9
5890.186sD$_2$	Na	30	6421.570s	Fe	7	6919.250s	A(O)	9
5896.155 D$_1$	Na	20	6439.293s	Ca	8	6923.553s	A(O)	9
5901.682s	A(wv)	6	6450.033s	Ca	6	6924.427s	A(O)	9
5914.430s	–, A(wv)	6	6494.004s	Ca	6	7191.755	A, –	6N
5919.860s	A(wv)	7	6495.213	Fe	8	7206.692	–, A	6
5930.406s	Fe	6	6546.479s	Ti–Fe	6			

Corrections to reduce Rowland's wave-lengths to Fabry and Buisson's system (the accepted standard, 1908); temperature 15° C, pressure 760 mm.:

Wave-length	4800.	4900.	5000.	5100.	5200.	5300.	5400.	5500.	5600.	5700.	5800.
Correction	—.179	—.176	—.173	—.170	—.166	—.172	—.212	—.217	—.218	—.213	—.209

Wave-length	5800.	5900.	6000.	6100.	6200.	6300.	6400.	6500.	6600.	6700.	6800.
Correction	—.209	—.209	—.213	—.214	—.213	—.210	—.209	—.210.			

STANDARD WAVE-LENGTHS. KAYSER'S IRON (ARC) LINES.

r = easily reversible.

Wave-length.	Intensity.	Correction.*	Wave-length.	Intensity.	Correction.*	Wave-length.	Intensity.	Correction.*	Wave-length.	Intensity.	Cor tio
2327.468	3		2518.198	8r		2742.506	10r		2973.254	8r	
31.384	3		22.950	20r		44.163	8r		73.366	5r	
32.869	3		23.754	4r		44.624	4r		81.565	7r	
38.073	1		27.525	10r		45.177	5r		83.690	10r	
43.567	3		29.223	8r		46.580	4r		87.410	4	—.
48.196	2		33.911	4		47.080	5r		90.511	4	
48.380	2		35.699	6r		50.238	10r		94.554	10r	
54.969	2		37.263	4r		55.834	5r		2999.630	8r	
59.187	3		41.064	8r		56.412	4r		3001.068	10r	
60.079	2		44.016	4r		57.413	4r		07.262	2	
60.373	2		46.072	10r		61.883	5r		07.409	2r	
64.904	2		49.708	8r		62.125	5r		08.254	8r	
66.678	2		56.404	2		68.621	5r		09.690	4r	
68.670	2		56.963	2		72.205	8r		16.043	3	
70.588	2		62.619	5	—.078	78.327	6r	—.102	16.305	3	
73.813	3r	—.076	67.001	4		78.946	2		17.747	8r	
75.273	3		75.445	3		81.936	3		20.619	4r	
80.840	4		78.012	3		88.207	10r		20.764	10r	
82.114	7r		84.623	5r		91.989	3		21.194	10r	
84.473	3		85.964	3		2797.877	2		25.960	8r	
88.711	2		88.102	5r	—.086	2804.622	5r		31.332	4	
91.563	2		98.456	5r		07.088	5r		31.753	4r	
95.709	5r		99.483	5r		13.391	8r	—.101	37.505	10r	
2399.322	5r		2599.663	4r		17.612	3		41.753	3	
2404.519	3		2606.920	3r		23.382	5r		41.860	3	
04.969	5r		07.155	3r		25.660	6r		47.719	10r	
06.742	5r		11.963	5r		25.803	4r		51.179	3	
10.601	5r		13.914	4r		32.543	8r		57.562	8r	
11.152	4r		17.706	4r		35.562	4r		59.202	10r	
13.393	4r	—.083	18.108	2r		38.231	3r		67.363	8r	
24.231	3		23.627	5r		43.742	3r		68.286	3	
31.126	2		25.754	5r		44.083	8r		75.850	6r	—.
35.234	(Si)	—.075	28.383	5r	—.087	51.910	5r	—.110	80.110	2	
39.834	4r		31.139	5r		59.007	3		83.853	5r	
40.201	4r		35.899	3r		63.973	3		91.687	3	
42.658	4r		44.085	3r		67.679	3		95.013	2	
47.808	4r		47.649	3		69.418	5r		3095.384	2	
53.568	2		51.800	2		74.284	5r	—.108	3100.057	4r	
57.686	5r		56.232	3		77.414	3		00.418	4r	
62.279	4r		66.897	3r		83.840	3		00.778	4r	
62.740	10r		73.315	2		90.000	3r		12.183	2	
65.244	5r		79.148	8r	—.083	94.617	3		16.747	3	
68.974	4r		80.544	3		2899.531	3		25.770	3	—.
72.436	4r		89.302	8r		2901.496	3		32.627	5r	
72.976	10r		90.153	2		07.630	3		40.503	3u	
74.906	4r		92.710	2		12.273	8r	—.116	44.096	3u	
78.657	C		2699.193	3		18.144	3		51.460	3u	
79.872	10r		2706.672	4r		23.409	5		57.157	4	
83.361	20r		08.663	2		25.479	3		60.764	3	
83.618	3r		14.503	5	—.084	29.119	8r		65.129	3	
84.280	8r		18.530	4r		37.030	10r		71.473	3	
88.232	10r		19.121	10r		41.462	8r	—.115	75.556	7	—.
89.844	8r		20.997	10r		44.519	3		78.122	5	
90.737	10r		23.671	8r		47.996	9r		80.339	7	
91.249	10r		25.024	4r		48.557	4		85.015	3	
93.331	7r		33.978	8r		54.061	9r		88.947	5	
2496.625	4r		35.566	8r		57.484	9r		91.778	5	
2501.228	8r		37.407	10r		65.379	7r		92.921	8	
07.991	4r		39.639	8r	—.089	67.019	10r		93.423	8	
2510.927	8r		2742.349	5r		2970.227	10r		3199.638	7	

Taken from Kayser's Handbuch der Spectroscopie.

* For reducing to Fabry and Buisson's system of wave-lengths see Table 149 (the accepted standard, 1908); tem
ture 15° C, pressure 760 mm.

STANDARD WAVE-LENGTHS. KAYSER'S IRON (ARC) LINES.

r = easily reversible.

Wave-length.	Intensity.	Correction.*	Wave-length.	Intensity.	Correction.*	Wave-length.	Intensity.	Correction.*	Wave-length.	Intensity.	Correction.*
3200.595	7		3490.721	6r		3790.242	5		4107.646	5	
05.515	8		3497.989	5r		95.149	8r		14.608	4	
10.953	5		3506.650	3		3798.658	6r		18.709	8	—.157
14.158	10		08.627	2		3801.822	6r		37.156	6	
19.701	5		08.663	2		06.847	3u		44.033	10u	
19.935	5		13.974	5r	—.154	13.202	5		54.662	4	
22.187	10r		21.415	5r		15.987	8r		71.069	4	
25.905	10r	—.115	26.196	4r		20.573	9r		75.799	5	
31.091	8		26.822	4		24.591	6r		81.918	5	
34.745	8		29.960	3		26.028	8r		87.221	8	
39.564	8		40.287	2		27.967	7r		91.611	8	—.170
44.308	5		58.672	5r		34.370	8r		4199.256	6	
48.333	5		65.535	8r		40.586	7r		4202.195	8	
51.357	5		70.257	8r		41.194	8r		10.521	5	
57.724	3		81.348	7r		50.114	8r		19.523	5	
62.413	2		85.478	4r		56.515	6r		22.387	5	
65.746	8		87.137	4r		60.054	10r		27.606	6	
71.129	5	—.126	94.767	4u		65.670	6ru	—.144	33.771	7	—.146
80.386	5		3599.781	2		72.640	4r		36.118	8	
84.720	3		3605.619	4		78.166	6r		45.423	5	
86.884	7		06.836	4	—.155	78.722	4		47.604	5	
3292.721	5		12.242	2		86.426	6r		50.299	8	
3306.106	7		17.934	5		87.193	5r		50.948	8	
06.479	7		18.918	8r		95.801	5r		60.656	9	
14.868	5		22.158	5		3899.853	5r		71.333	7	
17.251	2		30.506	3		3903.097	6r		71.933	10r	
28.992	5		31.617	6r		06.624	6	—.143	82.567	7	—.160
37.793	4		32.195	5		09.980	3		85.614	4	
42.034	3		40.541	5	—.150	13.784	3		91.631	3	
48.056	4		47.997	7r		20.404	6r		94.290	6r	
55.355	4		50.429	3		28.073	5r		4299.420	6r	
66.917	3		51.615	5		41.032	4		4308.072	7r	
67.675	5		55.625	3		45.269	2		09.542	4	
78.814	5r		59.673	5		48.927	4		15.255	6	—.166
80.242	4		69.674	5		56.610	3		25.941	8	
84.113	4		76.461	3		56.823	5		37.219	6	
89.882	2		80.062	4r		66.219	3		46.739	3	
94.721	3		83.205	3		69.411	6r		52.910	5	—.169
3397.117	3		87.609	4r		77.892	6	—.147	58.689	3	
3402.392	4		3695.202	3		84.112	4		67.759	5	
06.578	2		3702.180	2		86.330	4		69.954	5	
06.938	4		05.714	4r		96.147	3		76.104	6	
13.275	5		09.395	5r		3998.211	3		83.724	8r	
24.430	5r		20.083	10r		4007.429	3		4391.137	4	
27.263	4		22.710	6r		17.303	2		4404.929	8	
40.762	9r		27.769	5r		22.029	5	—.157	15.301	8	
41.138	8r		33.470	5r		30.670	3		27.490	6	—.176
44.025	7r		35.016	9r		32.796	2		30.801	5	
45.301	5	—.146	37.278	8r		44.776	2		42.522	6	
50.484	4		43.510	6r		45.978	10r		47.907	6	
58.454	3		45.710	7r		55.706	3		54.572	4	
60.067	4		48.409	7r		62.605	5		61.838	5	
66.006	5r		49.634	8r		63.755	10r		66.737	6	—.183
71.413	3		58.381	8r		68.138	5		69.566	6	
71.497	3		63.940	8r		71.901	8r		76.207	6	
75.600	6r		67.339	7r		79.999	3		84.420	5	
76.850	6r		76.606	3		84.666	5		89.929	4	
83.159	3		78.670	2		96.135	5		4494.755	6	—.183
3485.490	3	—.146	3788.031	5		4098.346	5				

Taken from Kayser's Handbuch der Spectroscopie.

* For reducing to Fabry and Buisson's system of wave-lengths see Table 149 (the accepted standard, 1908); temperature 15° C, pressure 760 mm.

WAVE-LENGTHS OF FRAUNHOFER LINES.

For convenience of reference the values of the wave-lengths corresponding to the Fraunhof lines usually designated by the letters in the column headed "index letters," are here tabulat separately. The values are in ten millionths of a millimetre, on the supposition that the D li value is 5896.155. The table is for the most part taken from Rowland's table of standard wav lengths.

Index Letter.	Line due to—	Wave-length in centimetres × 10^8.	Index Letter.	Line due to—	Wave-length in centimetres × 10^8.
A	O	7621.28*	G	Fe	4308.081
	O	7594.06*		Ca	4307.907
a	–	7164.725	g	Ca	4226.904
B	O	6870.182†	h or H_δ	H	4102.000
C or H_α	H	6563.045	H	Ca	3968.625
α	O	6278.303‡	K	Ca	3933.825
D_1	Na	5896.155	L	Fe	3820.586
D_2	Na	5890.186	M	Fe	3727.778
D_3	He	5875.985	N	Fe	3581.349
E_1	Fe	5270.558	O	Fe	3441.155
	Ca	5270.438	P	Fe	3361.327
E_2	Fe	5269.723	Q	Fe	3286.898
b_1	Mg	5183.791	R	Ca	3181.387
b_2	Mg	5172.856		Ca	3179.453
b_3	Fe	5169.220	S_1	Fe	3100.787
	Fe	5169.069	S_2	Fe	3100.430
b_4	Fe	5167.678		Fe	3100.046
	Mg	5167.497	s	Fe	3047.725
F or H_β	H	4861.527	T	Fe	3020.76
d	Fe	4383.721	t	Fe	2994.53
G′ or H_γ	H	4340.634	U	Fe	2947.99
f	Fe	4325.939			

* The two lines here given for A are stated by Rowland to be: the first, a line "beginning at the head of A, o side edge;" the second, a "single line beginning at the tail of A."

† The principal line in the head of B.

‡ Chief line in the α group.

See Table 152, Rowland's Solar Wave-lengths (foot of page) for correction to reduce these values to Fabry-Buiss system of wave-lengths.

PHOTOMETRIC STANDARDS

) primary photometric standard has been generally adopted by the various governments. In
nany the Hefner lamp is most used; in England the Pentane lamp and sperm candles are
; in France the Carcel lamp is preferred; in America the Pentane and Hefner lamps are used
me extent, but candles are more largely employed in gas photometry. For the photometry
ectric lamps, and generally in accurate photometric work, electric lamps, standardized at a
nal standardizing institution, are commonly employed.

ie "International candle" is the name recently employed to designate the value of the candle
aintained by coöperative effort between the national laboratories of England, France, and
rica; and the value of various photometric units in terms of this international candle is given
e following table (taken from Circular No. 15 of the Bureau of Standards).

1 International Candle = 1 Pentane Candle.
1 International Candle = 1 Bougie Decimale.
1 International Candle = 1 American Candle.
1 International Candle = 1.11 Hefner Unit.
1 International Candle = 0.104 Carcel Unit.

ierefore 1 Hefner Unit = 0.90 International Candle.

ie values of the flame standards most commonly used are as follows:

1. Standard Pentane Lamp, burning pentane . . . . . 10.0 candles.
2. Standard Hefner Lamp, burning amyl acetate . . . . . 0.9 candles.
3. Standard Carcel Lamp, burning colza oil . . . . . 9.6 candles.
4. Standard English Sperm Candle, approximately . . . . 1.0 candles.

ight differences in candle power are found in different lamps, even when made as accurately
ossible to the same specifications. Hence these so-called primary standards should be them-
es standardized.

SENSITIVENESS OF THE EYE TO RADIATION.

(Compiled from Nutting, Bulletin of the Bureau of Standards.)

Radiation is easily visible to most eyes from 0.330μ in the violet to 0.770μ in the red. At low intensities approaching threshold values (rod vision) the maximum of spectral sensibility lies in the green at about 0.510μ for 90% of all persons. At higher intensities with the establishment of cone vision the maximum shifts towards the yellow at least as far as 0.560μ.

TABLE 156. — Variation of the Sensitiveness of the Eye with the Wave-length at Low Intensities (near Threshold Values). König.

λ	.410	.430	.450	.470	.490	.510	.530	.550	.570	.590	.610
Mean sensitiveness	0.02	0.06	0.23	0.49	0.81	1.00	0.81	0.49	0.22	0.077	0.026

TABLE 157. — Variation of Sensitiveness to Radiation of Greater Intensities.

The sensibility is approximately proportional to the intensity over a wide range. The ratio of optical- to radiation-intensity increases more rapidly for the red than for the blue or green (Purkinje phenomenon).

The intensity is given for the spectrum at 0.535μ (green).

Intensity (metre-candles) =	.00024	.00225	.0360	.575	2.30	9.22	36.9	147.6	590.4
Ratio to preceding step =	-	9.38	16	16	4	4	4	4	4
Wave-length, λ.	Sensitiveness.								
0.430μ	.081	.093	.127	.128	.114	.114	–	–	–
.450	.33	.30	.29	.31	.23	.175	.16	–	–
.470	.63	.59	.54	.58	.51	.29	.26	.23	–
.490	.96	(.89)	(.76)	(.89)	(.83)	.50	.45	.38	.35
.505	1.00	1.00	1.00	1.00	.99	(.76)	.66	.61	.54
.520	.88	.86	.86	.94	.99	(.85)	.85	.85	.82
.535	.61	.62	.63	.72	.91	(.98)	.98	.99	.98
.555	.26	.30	.34	.41	.62	.84	.93	.97	.98
.575	.074	.102	.122	.168	(.39)	(.63)	(.76)	(.82)	(.84)
.590	.025	.034	.054	.091	.27	.49	.61	.68	.69
.605	.008	.012	.024	.056	.173	.35	(.45)	.54	.55
.625	.004	.004	.011	.027	.098	.20	.27	.35	.35
.650	.000	.000	.003	.007	.025	.060	.085	.122	.133
.670	.000	.000	.001	.002	.007	.017	.025	.030	.030
λ, maximum sensitiveness	.503	.504	.504	.508	.513	.530	.541	.543	.544

TABLE 158. — Sensibility to Small Differences in Intensity measured as a Fraction of the Whole.

λ =	.670	.605	.575	.505	.470	.430	White
I_0 in m. c. =	0.060	0.0056	0.0029	0.00017	0.00012	0.00013	0.00072
I	$\delta I : I$ König's data, measures from one normal person only.						
1,000,000	–	–	–	–	–	–	.036
200,000	–	.042	–	–	–	–	.027
100,000	–	.024	.032	–	–	–	.019
50,000	.021	.025	.026	–	–	–	.017
20,000	.016	.018	.020	.019	–	–	.017
10,000	.016	.016	.018	.018	–	–	.018
5,000	.018	.016	.017	.016	–	–	.018
2,000	.016	.018	.018	.017	.018	–	.018
1,000	.017	.020	.018	.018	.017	.018	.018
500	.020	.021	.018	.019	.018	.021	.019
200	.022	.022	.022	.022	.021	.024	.022
100	.029	.028	.027	.024	.022	.025	.030
50	.038	.038	.032	.025	.025	.027	.032
10	.065	.061	.058	.036	.037	.040	.048
5	.092	.103	.089	.049	.046	.049	.059
1	.258	.212	.170	.080	.088	.074	.123
0.5	.376	.276	.21	.091	.096	.097	.188
0.10	–	–	.40	.133	.138	.137	.377
0.05	–	–	–	.183	.185	.154	.484
0.01	–	–	–	.271	.289	.249	–
0.005	–	–	–	.325	.300	.312	–

The sensibility to small differences in intensity is independent of the intensity (Fechner's law). About 0.016 for moderate intensities. Greater for extreme values.

It is independent of wave-length, extremes excepted (König's law).

Sensibility to slight differences in wave-length has two pronounced maxima (one in the yellow, one in the green) and two slight maxima (extreme blue, extreme red).

The visual sensation as a function of the time approaches a constant value with the lapse of time. With blue light there seems to be a pronounced maximum at 0.07 sec., with red a slight one at 0.12 seconds, with green the sensation rises steadily to its final value. For lower intensities these max. occur later.

An intensity of 500 metre-candles is about that on a horizontal plane on a cloudy day.

TABLE 159.—Solar Energy and its Absorption by the Earth's Atmosphere.

The following values depend upon the formula $e_m = e_o a^m$, where e_m is the observed value of the solar energy after transmission through a mass of air, m; m = unity when the sun is in the zenith, and approximately = sec. zenith distance for other positions of the sun. e_o = the energy which would have been observed had there been no absorbing atmosphere; a is the amount transmitted when the sun is in the zenith or when $m = 1$.

Wave-length. μ	Transmission coefficient, a.				Intensity of Solar Energy.										
	Wash-ington.	Mount Wilson.	Mount Whit-ney.	One mile nearer Earth.	Mt Whit-ney.		Mount Wilson.				Washington.				
					m=0	m=1	m=1	2	4	6	m=1	2	3	4	6
0.30	–	(.485)	.522	–	95	50	46	22	05	1.2	–	–	–	–	–
.32	–	(.562)	.615	–	195	120	110	62	19	6.2	–	–	–	–	–
.34	–	.626	.687	–	305	210	191	120	47	18	–	–	–	–	–
.36	–	.676	.745	–	420	313	284	192	88	40	–	–	–	–	–
.38	(.360)	.713	.788	.505	501	394	357	255	129	66	180	65	23	8	1.1
.40	.542	.746	.821	.725	580	476	433	323	180	100	314	171	92	50	15
.46	.653	.816	.879	.800	730	642	596	486	323	215	477	311	203	133	57
.50	.704	.850	.902	.829	685	618	582	495	358	258	482	340	239	169	84
.60	.762	.884	.942	.862	590	556	522	461	360	281	450	343	261	199	116
.70	.838	.937	.966	.894	454	439	425	399	350	307	380	319	267	224	157
.80	.867	.955	.981	.909	342	336	327	312	285	260	297	257	223	193	145
1.00	.901	.968	.991	.930	190	188	184	178	167	156	171	154	139	125	102
1.50	.923	.977*	.956	.950	82	78	80*	78*	75*	71*	76	70	64	60	51
2.00	.909	.969*	.925	.932	30	28	29*	28*	26*	25*	27	25	23	20	17

* These may be too high because of the usual increased humidity towards noon at Mount Wilson.

TABLE 160.—Solar Constant.

Solar constant (amount of energy falling at normal incidence on one square centimetre per minute on body at earth's mean distance) = 1.92 small calories. Mount Wilson and Mount Whitney observations.

Computed effective temperature of the sun: Goldhammer's method (Ann. der Phys. (4) 25, 905, 1908), 6200° Absolute; from form of black body curves, 6000 to 7000°; from λ max. = 2930, 6370°; from Total Radiation, $J = 76.8 \times 10^{-12}$, 5830°.

TABLE 161.—Distribution of Brightness (Radiation) over the Solar Disk.

(These observations extend over only a small portion of a sun-spot cycle.)

Wave-length	μ 0.323	μ 0.386	μ 0.433	μ 0.456	μ 0.481	μ 0.501	μ 0.534	μ 0.604	μ 0.670	μ 0.699	μ 0.866	μ 1.031	μ 1.225	μ 1.655	μ 2.097
Fraction Radius. 0.00	144	338	456	515	511	489	463	399	333	307	174	111	77.6	39.5	14.0
0.40	128	312	423	486	483	463	440	382	320	295	169	108	75.7	38.9	13.8
0.55	120	289	395	455	456	437	417	365	308	284	163	105.5	73.8	38.2	13.6
0.65	112	267	368	428	430	414	396	348	295	273	159	103	72.2	37.6	13.4
0.75	99	240	333	390	394	380	366	326	281	258	152	99	69.8	36.7	13.1
0.825	86	214	296	351	358	347	337	304	262	243	145	94.5	67.1	35.7	12.8
0.875	76	188	266	317	324	323	312	284	247	229	138	90.5	64.7	34.7	12.5
0.92	64	163	233	277	290	286	281	259	227	212	130	86	61.6	33.6	12.2
0.95	49	141	205	242	255	254	254	237	210	195	122	81	58.7	32.3	11.7

TABLE 162.—Relative Distribution in Normal Spectrum of Sun and Sky-light at Mount Wilson.

Zenith distance about 50°.

	μ	μ	μ	μ	μ	μ	C	D	b	F
Place in Spectrum	0.422	0.457	0.491	0.566	0.614	0.660				
Intensity Sunlight	186	232	227	211	191	166				
Intensity Sky-light	1194	986	701	395	231	174				
Ratio at Mount Wilson	642	425	309	187	121	105	25	35	60	77
Ratio computed by Rayleigh	–	–	–	–	–	–	25	40	63	80
Ratio observed by Rayleigh	–	–	–	–	–	–	25	41	71	90

Derived from vol. II and unpublished data of the Astrophysical Observatory of the Smithsonian Institution, Abbot and Fowle, Astrophysical Journal, 29, 1909, and Schwartzchild and Villiger, same Journal, 23, 1906.

TABLE 163. — Glasses Made by Schott and Gen, Jena.

The following constants are for glasses made by Schott and Gen, Jena: n_A, n_C, n_D, n_F, n_G, are the indices of refraction in air for A=0.7682μ, C=0.6563μ, D=0.5893, F=0.4861, G′=0.4341. $v=(n_D-1)/(n_F-n_C)$. Ultra-violet indices: Simon, Wied. Ann. 53, 1894. Infra-red: Rubens, Wied. Ann. 45, 1892. Table is revised from Landolt, Börnstein and Meyerhoffer, Kayser, Handbuch der Spectroscopie, and Schott and Gen's list No. 751, 1909. See also Hovestadt's "Jena Glass."

Kind of Light and Wave-length.		O 546	O 381	O 184	O 102	O 165	S 57
Catalogue Type =							
Designation =		Zinc-Crown.	Higher Dispersion Crown.	Light Silicate Flint.	Heavy Silicate Flint.	Heavy Silicate Flint.	Heaviest Silicate Flint.
Melting Number =		1092	1151	451	469	500	163
v =		60.7	51.8	41.1	33.7	27.6	22.2
Cd	0.2763μ	1.56759	–	–	–	–	–
Cd	.2837	1.56372	–	–	–	–	–
Cd	.2980	1.55723	1.57093	1.65397	–	–	–
Cd	.3403	1.54369	1.55262	1.63320	1.71968	1.85487	–
Cd	.3610	1.53897	1.54664	1.61388	1.70536	1.83263	–
H	.4340μ	1.52788	1.53312	1.59355	1.67561	1.78800	1.94493
H	.4861	1.52299	1.52715	1.58515	1.66367	1.77091	1.91890
Na	.5893	1.51698	1.52002	1.57524	1.64985	1.75130	1.88995
H	.6563	1.51446	1.51712	1.57119	1.64440	1.74368	1.87893
K	.7682	1.51143	1.51368	1.56669	1.63820	1.73530	1.86702
	.800μ	1.5103	1.5131	1.5659	1.6373	1.7339	1.8650
	1.200	1.5048	1.5069	1.5585	1.6277	1.7215	1.8481
	1.600	1.5008	1.5024	1.5535	1.6217	1.7151	1.8396
	2.000	1.4967	1.4973	1.5487	1.6171	1.7104	1.8316
	2.400	–	–	1.5440	1.6131	–	1.8286

Percentage composition of the above glasses:

O 546, SiO_2, 65.4; K_2O, 15.0; Na_2O, 5.0; BaO, 9.6; ZnO, 2.0; Mn_2O_3, 0.1; As_2O_3, 0.4; B_2O_3, 2.5.
O 381, SiO_2, 68.7; PbO, 13.3; Na_2O, 15.7; ZnO, 2.0; MnO_2, 0.1; As_2O_5, 0.2.
O 184, SiO_2, 53.7; PbO, 36.0; K_2O, 8.3; Na_2O, 1.0; Mn_2O_3, 0.06; As_2O_3, 0.3.
O 102, SiO_2, 40.0; PbO, 52.6; K_2O, 6.5; Na_2O, 0.5; Mn_2O_3, 0.09; As_2O_5, 0.3.
O 165, SiO_2, 29.26; PbO, 67.5; K_2O, 3.0; Mn_2O_3, 0.04; As_2O_3, 0.2.
S 57, SiO_2, 21.9; PbO, 78.0; As_2O_5, 0.1.

TABLE 164. — Jena Glasses.

No. and Type of Jena Glass.	n_D for D	n_F-n_C	$v=\frac{n_D-1}{n_F-n_C}$	n_D-n_A	n_F-n_D	$n_{G'}-n_F$	Specific Weight.
O 225 Light phosphate crown	1.5159	.00737	70.0	.00485	.00515	.00407	2.58
O 802 Boro-silicate crown	1.4967	0765	64.9	0504	0534	0423	2.38
UV 3109 Ultra-violet crown	1.5035	0781	64.4	0514	0546	0432	2.41
O 227 Barium-silicate crown	1.5399	0909	59.4	0582	0639	0514	2.73
O 114 Soft-silicate crown	1.5151	0910	56.6	0577	0642	0521	2.55
O 608 High-dispersion crown	1.5149	0943	54.6	0595	0666	0543	2.60
UV 3248 Ultra-violet flint	1.5332	0964	55.4	0611	0680	0553	2.75
O 381 High-dispersion crown	1.5262	1026	51.3	0644	0727	0596	2.70
O 602 Baryt light flint	1.5676	1072	53.0	0675	0759	0618	3.12
S 389 Borate flint	1.5686	1102	51.6	0712	0775	0629	2.83
O 726 Extra light flint	1.5398	1142	47.3	0711	0810	0669	2.87
O 154 Ordinary light flint	1.5710	1327	43.0	0819	0943	0791	3.16
O 184 " " "	1.5900	1438	41.1	0882	1022	0861	3.28
O 748 Baryt flint	1.6235	1599	39.1	9965	1142	0965	3.67
O 102 Heavy flint	1.6489	1919	33.8	1152	1372	1180	3.87
O 41 " "	1.7174	2434	29.5	1439	1749	1521	4.49
O 165 " "	1.7541	2743	27.5	1607	1974	1730	4.78
S 386 Heavy flint	1.9170	4289	21.4	2451	3109	2808	6.01
S 57 Heaviest flint	1.9626	4882	19.7	2767	3547	3252	6.33

TABLE 165. — Change of Indices of Refraction for 1° C in Units of the Fifth Decimal Place.

No. and Designation.	Mean Temp.	C	D	F	G′	$\frac{-\Delta n}{n}100$
S 57 Heavy silicate flint	58.8°	1.204	1.447	2.090	2.810	0.0166
O 154 Light silicate flint	58.4	0.225	0.261	0.334	0.407	0.0078
O 327 Baryt flint light	58.3	—0.008	0.014	0.080	0.137	0.0079
O 225 Light phosphate crown	58.1	—0.202	—0.190	—0.168	—0.142	0.0049

Pulfrich, Wied. Ann. 45, p. 609, 1892.

INDEX OF REFRACTION.

Indices of Refraction for the various Alums.*

R	Density.	Temp. C.°	Index of refraction for the Fraunhofer lines.							
			a	B	c	D	E	b	F	G
Aluminium Alums. $RAl(SO_4)_2+12H_2O$.†										
Na	1.667	17–28	1.43492	1.43563	1.43653	1.43884	1.44185	1.44231	1.44412	1.44804
$NH_3(CH_3)$	1.568	7–17	.45013	.45062	.45177	.45410	.45691	.45749	.45941	.46363
K	1.735	14–15	.45226	.45303	.45398	.45645	.45934	.45996	.46181	.46609
Rb	1.852	7–21	.45232	.45328	.45417	.45660	.45955	.45999	.46192	.46618
Cs	1.961	15–25	.45437	.45517	.45618	.45856	.46141	.46203	.46386	.46821
NH_4	1.631	15–20	.45509	.45599	.45693	.45939	.46234	.46288	.46481	.46923
Tl	2.329	10–23	.49226	.49317	.49443	.49748	.50128	.50209	.50463	.51076
Indium Alums. $RIn(SO_4)_2+12H_2O$.†										
Rb	2.065	3–13	1.45942	1.46024	1.46126	1.46381	1.46694	1.46751	1.46955	1.47402
Cs	2.241	17–22	.46091	.46170	.46283	.46522	.46842	.46897	.47105	.47562
NH_4	2.011	17–21	.46193	.46259	.46352	.46636	.46953	.47015	.47234	.47750
Gallium Alums. $RGa(SO_4)_2+12H_2O$.†										
Cs	2.113	17–22	1.46047	1.46146	1.46243	1.46495	1.46785	1.46841	1.47034	1.47481
K	1.895	19–25	.46118	.46195	.46296	.46528	.46842	.46904	.47093	.47548
Rb	1.962	13–15	.46152	.46238	.46332	.46579	.46890	.46930	.47126	.47581
NH_4	1.777	15–21	.46390	.46485	.46575	.46835	.47146	.47204	.47412	.47864
Tl	2.477	18–20	.50112	.50228	.50349	.50665	.51057	.51131	.51387	.52007
Chrome Alums. $RCr(SO_4)_2+12H_2O$.†										
Cs	2.043	6–12	1.47627	1.47732	1.47836	1.48100	1.48434	1.48491	1.48723	1.49280
K	1.817	6–17	.47642	.47738	.47865	.48137	.48459	.48513	.48753	.49309
Rb	1.946	12–17	.47660	.47756	.47868	.48151	.48486	.48522	.48775	.49323
NH_4	1.719	7–18	.47911	.48014	.48125	.48418	.48744	.48794	.49040	.49594
Tl	2.386	9–25	.51692	.51798	.51923	.52280	.52704	.52787	.53082	.53808
Iron Alums. $RFe(SO_4)_2+12H_2O$.†										
K	1.806	7–11	1.47639	1.47706	1.47837	1.48169	1.48580	1.48670	1.48939	1.49605
Rb	1.916	7–20	.47700	.47770	.47894	.48234	.48654	.48712	.49003	.49700
Cs	2.061	20–24	.47825	.47921	.48042	.48378	.48797	.48867	.49136	.49838
NH_4	1.713	7–20	.47927	.48029	.48150	.48482	.48921	.48993	.49286	.49980
Tl	2.385	15–17	.51674	.51790	.51943	.52365	.52859	.52946	.53284	.54112

* According to the experiments of Soret (Arch. d. Sc. Phys. Nat. Genève, 1884, 1888, and Comptes Rendus, 1885).
† R stands for the different bases given in the first column.

TABLE 167.

INDEX OF REFRACTION.

Index of Refraction of Metals and Metallic Oxides.

(a) Experiments of Kundt* by transmission of light through metallic prisms of small angle.

Name of substance.	Index of refraction for		
	Red.	White.	Blue.
Silver	–	0.27	–
Gold	0.38	0.58	1.00
Copper	0.45	0.65	0.95
Platinum	1.76	1.64	1.44
Iron	1.81	1.73	1.52
Nickel	2.17	2.01	1.85
Bismuth	2.61	2.26	2.13
Gold and gold oxide	1.04	–	1.25
" " "	0.89	0.99	1.33
" " " †	–	2.03	–
Bismuth oxide	–	1.91	–
Iron oxide	1.78	2.11	2.36
Nickel oxide	2.18	2.23	2.39
Copper oxide	2.63	2.84	3.18
Platinum and platinum oxide	3.31	3.29	2.90
" " "	4.99	4.82	4.40

(b) Experiments of Du Bois and Rubens by transmission of light through prisms of small angle.

The experiments were similar to those of Kundt, and were made with the same spectrometer. Somewhat greater accuracy is claimed for these results on account of some improvements introduced, mainly by Prof. Kundt, into the method of experiment. There still remains, however, a somewhat large chance of error.

Name of metal.	Index of refraction for light of the following color and wave-length.				
	Red (Li_α). $\lambda = 67.1$	"Red." $\lambda = 64.4$	Yellow (D). $\lambda = 58.9$	Blue (F). $\lambda = 48.6$	Violet (G). $\lambda = 43.1$ ‡
Nickel	2.04	1.93	1.84	1.71	1.54
Iron	3.12	3.06	2.72	2.43	2.05
Cobalt	3.22	3.10	2.76	2.39	2.10

(c) Experiments of Drude.

The following table gives the results of some of Drude's experiments.§ The index of refraction is derived in this case from the constants of elliptic polarization by reflection, and are for sodium light.

Metal.	Index of refraction.	Metal.	Index of refraction.
Aluminium	1.44	Mercury	1.73
Antimony	3.04	Nickel	1.79
Bismuth	1.90	Platinum	2.06
Cadmium	1.13	Silver	0.181
Copper	0.641	Steel	2.41
Gold	0.366	Tin, solid	1.48
Iron	2.36	" fluid	2.10
Lead	2.01	Zinc	2.12
Magnesium	0.37		

* "Wied. Ann." vol. 34, and "Phil. Mag." (5) vol. 26.
† Nearly pure oxide.
‡ Wave-lengths λ are in millionths of a centimetre.
§ "Wied. Ann." vol. 39.

TABLE 168. — Index of Refraction of Rock Salt in Air.

λ(μ).	n.	Observer.	λ(μ).	n.	Observer.	λ(μ).	n.	Observer.
0.185409	1.89348	M	0.88396	1.534011	L	5.8932	1.516014	P
.204470	1.76964	"	.972298	1.532532	"	"	1.515553	L
.291368	1.61325	"	.98220	1.532435	P	6.4825	1.513628	P
.358702	1.57932	"	1.036758	1.531762	L	"	1.513467	L
.441587	1.55962	"	1.1786	1.530372	P	7.0718	1.511062	P
.486149	1.55338	"	"	1.530374	L	7.6611	1.508318	"
"	1.553406	L	1.555137	1.528211	"	7.9558	1.506804	"
"	1.553399	P	1.7680	1.527440	P	8.8398	1.502035	"
.58902	1.544340	L	"	1.527441	L	10.0184	1.494722	"
.58932	1.544313	P	2.073516	1.526554	"	11.7864	1.481816	"
.656304	1.540672	P	2.35728	1.525863	P	12.9650	1.471720	"
"	1.540702	L	"	1.525849	L	14.1436	1.460547	"
.706548	1.538633	P	2.9466	1.524534	P	14.7330	1.454404	"
.766529	1.536712	P	3.5359	1.523173	"	15.3223	1.447494	"
.76824	1.53666	M	4.1252	1.521648	P	15.9116	1.441032	"
.78576	1.536138	P	"	1.521625	L	20.57	1.3735	RN
.88396	1.534011	P	5.0092	1.518978	P	22.3	1.340	"

$$n^2 = a^2 + \frac{M_1}{\lambda^2 - \lambda_1^2} + \frac{M_2}{\lambda^2 - \lambda_2^2} - k\lambda^2 - h\lambda^4 \text{ or } = b^2 + \frac{M_1}{\lambda^2 - \lambda_1^2} + \frac{M_2}{\lambda^2 - \lambda_2^2} - \frac{M_3}{\lambda_3^2 - \lambda^2}$$

where $a^2 = 2.330165$ $\quad \lambda_2^2 = 0.02547414$ $\quad b^2 = 5.680137$

$M_1 = 0.01278685$ $\quad k = 0.0009285837$ $\quad M_3 = 12059.95$

$\lambda_1^2 = 0.0148500$ $\quad h = 0.000000286086$ $\quad \lambda_3^2 = 3600.$ (P)

$M_2 = 0.005343924$

TABLE 169.— Change of Index of Refraction for 1° C in Units of the 5th Decimal Place.

0.202μ	+3.134	Mi	0.441μ	−3.425	Mi	C line	−3.749	Pl	0.760μ	−3.73	L
.210	+1.570	"	.508	−3.517	"	D "	−3.739	"	1.368	−3.88	L
.224	−0.187	"	.643	−3.636	"	F "	−3.648	"	1.88	−3.85	L
.298	−2.727	"				G′ "	−3.585	"	4.3	−3.82	L

L Annals of the Astrophysical Observatory of the Smithsonian Institution, Vol. I, 1900.
M Martens, Ann. d. Phys. 6, 1901, 8, 1902.
Mi Micheli, Ann. d. Phys. 7, 1902.
P Paschen, Wied. Ann. 26, 1908.
Pl Pulfrich, Wied. Ann. 45, 1892.
RN Rubens and Nichols, Wied. Ann. 60, 1897.

TABLE 170.— Index of Refraction of Silvine (Potassium Chloride) in Air.

λ(μ).	n	Observer.	λ(μ).	n.	Observer.	λ(μ).	n.	Observer.
0.185409	1.82710	M	1.1786	1.478311	P	8.2505	1.462726	P
.200090	1.71870	"	"	1.47824	W	"	1.46276	W
.21946	1.64745	"	1.7680	1.475890	P	8.8398	1.460858	P
.257317	1.58125	"	"	1.47589	W	"	1.46092	W
.281640	1.55836	"	2.35728	1.474751	P	10.0184	1.45672	P
.308227	1.54136	"	2.9466	1.473834	"	"	1.45673	W
.358702	1.52115	"	"	1.47394	W	11.786	1.44919	P
.394415	1.51219	"	3.5359	1.473049	P	"	1.44941	W
.407832	1.50044	"	"	1.47304	W	12.965	1.44346	P
.508666	1.49620	"	4.7146	1.471122	P	"	1.44385	W
.58932	1.490443	P	"	1.47129	W	14.144	1.43722	P
.67082	1.48669	M	5.3039	1.470013	P	15.912	1.42617	"
.78576	1.483282	P	"	1.47001	W	17.680	1.41403	"
.88398	1.481422	P	5.8932	1.468804	P	20.60	1.3882	RN
.98220	1.480084	"	"	1.46880	W	22.5	1.369	"

$$n^2 = a^2 + \frac{M_1}{\lambda^2 - \lambda_1^2} + \frac{M_2}{\lambda^2 - \lambda_2^2} - k\lambda^2 - h\lambda^4 \text{ or } = b^2 + \frac{M_1}{\lambda^2 - \lambda_1^2} + \frac{M_2}{\lambda^2 - \lambda_2^2} + \frac{M_3}{\lambda_3^2 - \lambda^2}$$

$a^2 = 2.174967$ $\quad \lambda_2^2 = 0.0255550$ $\quad b^2 = 3.866619$

$M_1 = 0.008344206$ $\quad k = 0.000513495$ $\quad M_3 = 5569.715$

$\lambda_1^2 = 0.0119082$ $\quad h = 0.000000167587$ $\quad \lambda_3^2 = 3292.47$ (P)

$M_2 = 0.00698382$

W Weller, see Paschen's article. Other references as under Table 169, above.

INDEX OF REFRACTION.

TABLE 171. — Index of Refraction of Fluorite in Air.

λ (μ)	n	Observer	λ (μ)	n	Observer	λ (μ)	n	Observer.
0.1856	1.50940	S	1.4733	1.42641	P	4.1252	1.40855	P
.19881	1.49629	"	1.5715	1.42596	"	4.4199	1.40559	"
.21441	1.48462	"	1.6206	1.42582	"	4.7146	1.40238	"
.22645	1.47762	"	1.7680	1.42507	"	5.0092	1.39898	"
.25713	1.46476	"	1.9153	1.42437	"	5.3036	1.39529	"
.32525	1.44987	"	1.9644	1.42413	"	5.5985	1.39142	"
.34555	1.44697	"	2.0626	1.42359	"	5.8932	1.38719	"
.39681	1.44214	"	2.1608	1.42308	"	6.4825	1.37819	"
.48607	1.43713	P	2.2100	1.42288	"	7.0718	1.36805	"
.58930	1.43393	P	2.3573	1.42199	"	7.6612	1.35680	"
.65618	1.43257	S	2.5537	1.42088	"	8.2505	1.34444	"
.68671	1.43200	"	2.6519	1.42016	"	8.8398	1.33079	"
.71836	1.43157	"	2.7502	1.41971	"	9.4291	1.31612	"
.76040	1.43101	"	2.9466	1.41826	"	51.2	3.47	RA
.8840	1.42982	P	3.1430	1.41707	"	61.1	2.66	"
1.1786	1.42787	"	3.2413	1.41612	"	∞	2.63	S
1.3756	1.42690	"	3.5359	1.41379	"			
1.4733	1.42641	"	3.8306	1.41120	"	References under Table 173.		

$$n^2 = a^2 + \frac{M_1}{\lambda^2 - \lambda_1^2} - e\lambda^2 - f\lambda^4 \text{ or } = b^2 + \frac{M_2}{\lambda^2 - \lambda_2^2} + \frac{M_3}{\lambda^2 - \lambda_3^2}$$

where $a^2 = 2.03882$ $\quad f = 0.000002916$ $\quad M_3 = 5114.65$

$M_1 = 0.0062183$ $\quad b^2 = 6.09651$ $\quad \lambda_3^2 = 1260.56$

$\lambda_1^2 = 0.007706$ $\quad M_2 = 0.0061386$ $\quad \lambda_3 = 0.0940\mu$

$e = 0.0031999$ $\quad \lambda_2^2 = 0.00884$ $\quad \lambda_2 = 35.5\mu$ (P)

TABLE 172. — Change of Index of Refraction for 1° C in Units of the 5th Decimal Place.

C line, −1.220; D, −1.206; F, −1.170; G, −1.142. (Pl)

TABLE 173. — Index of Refraction of Iceland Spar ($CaCO_3$) in Air.

λ (μ)	n_o	n_e	Observer.	λ (μ)	n_o	n_e	Observer.	λ (μ)	n_o	n_e	Observer.
0.198	–	1.5780	M	0.508	1.6653	1.4896	M	0.991	1.6438	1.4802	C
.200	1.9028	1.5765	"	.533	1.6628	1.4884	"	1.229	1.6393	1.4787	"
.208	1.8673	1.5664	"	.589	1.6584	1.4864	"	1.307	1.6379	1.4783	"
.226	1.8130	1.5492	–	.643	1.6550	1.4849	"	1.497	1.6346	1.4774	"
.298	1.7230	1.5151	C	.656	1.6544	1.4846	"	1.682	1.6313	–	"
.340	1.7008	1.5056	M	.670	1.6537	1.4843	"	1.749	–	1.4764	"
.361	1.6932	1.5022	C	.760	1.6500	1.4826	–	1.849	1.6280	–	"
.410	1.6802	1.4964	–	.768	1.6497	1.4826	M	1.908	–	1.4757	"
.434	1.6755	1.4943	M	.801	1.6487	1.4822	C	2.172	1.6210	–	"
.486	1.6678	1.4907	"	.905	1.6458	1.4810	"	2.324	–	1.4739	"

C Carvallo, J. de Phys. (3), 9, 1900.
M Martens, Ann. der Phys. (4) 6, 1901, 8, 1902.
P Paschen, Wied. Ann. 56, 1895.
Pl Pulfrich, Wied. Ann 45, 1892.
RA Rubens-Aschkinass, Wied. Ann. 67, 1899.
S Starke, Wied. Ann. 60, 1897.

TABLE 174. — Index of Refraction of Nitroso-dimethyl-aniline. (Wood.)

λ	n	λ	n	λ	n	λ	n	λ	n
0.497	2.140	0.525	1.945	0.584	1.815	0.636	1.647	0.713	1.718
.500	2.114	.536	1.909	.602	1.796	.647	1.758	.730	1.713
.506	2.074	.546	1.879	.611	1.783	.659	1.750	.749	1.709
.508	2.025	.557	1.857	.620	1.778	.669	1.743	.763	1.697
.516	1.985	.569	1.834	.627	1.769	.696	1.723		

Nitroso-dimethyl-aniline has enormous dispersion in yellow and green, metallic absorption in violet. See Wood. Phil. Mag. 1903.

TABLE 175.

INDEX OF REFRACTION.

Index of Refraction of Quartz (SiO_2).

Wave-length.	Index Ordinary Ray.	Index Extraordinary Ray.	Temperature ° C.	Wave-length.	Index Ordinary Ray.	Index Extraordinary Ray.	Temperature ° C.
0.185	1.67582	1.68999	18	0.656	1.54189	1.55091	18
.193	.65997	.67343	"	.686	.54099	.54998	"
.198	.65090	.66397	"	.760	.53917	.54811	"
.206	.64038	.65300	"	1.160	.5329		–
.214	.63041	.64264	"	.969	.5216		–
.219	.62494	.63698	"	2.327	.5156		–
.231	.61399	.62560	"	.84	.5039		–
.257	.59622	.60712	"	3.18	.4944		–
.274	.58752	.59811	"	.63	.4799	Rubens.	–
.340	.56748	.57738	"	.96	.4679		–
.396	.55815	.56771	"	4.20	.4569		–
.410	.55650	.56600	"	5.0	.417		–
.486	.54968	.55896	"	6.45	.274		–
0.598	1.54424	1.55334	"	7.0	1.167		–

Except Rubens' values, — means from various authorities.

TABLE 176.

INDEX OF REFRACTION.

Various Monorefringent or Optically Isotropic Solids.

Substance.	Line of Spectrum.	Index of Refraction.	Authority.
Agate (light color)	red	1.5374	De Senarmont
Ammonium chloride	D	1.6422	Grailich.
Arsenite	D	1.755	DesCloiseaux.
Barium nitrate	D	1.5716	Fock.
Bell metal	D	1.0052	Beer.
Blende	Li	2.34165	Ramsay.
	Na	2.36923	
	Tl	2.40069	
Boric acid	C	1.46245	Bedson and Carleton Willi
	D	1.46303	
	F	1.47024	
Borax (vitrified)	C	1.51222	
	D	1.51484	
	F	1.52068	
Camphor	D	1.532	Kohlrausch.
		1.5462	Mulheims.
Diamond (colorless)	red	2.414	DesCloiseaux.
	green	2.428	
Diamond (brown)	B	2.46062	Schrauf.
	D	2.46986	
	E	2.47902	
Ebonite	D	1.6	Ayrton & Perry
Fuchsin	A	2.03	Means.
	B	2.19	
	C	2.33	
	G	1.97	
	H	1.32	
Garnet (different varieties)	D	1.74 to 1.90	Various.
Gum arabic	red	1.480	Jamin.
" "	"	1.514	Wollaston.
Hanyne	D	1.4961	Tschichatschef
Helvine	D	1.739	Levy & Lecroi
Obsidian	D	1.482 to 1.496	Various.
Opal	D	1.406 to 1.450	"
Pitch	red	1.531	Wollaston.
Potassium bromide	D	1.5593	Topsöe and Christiansen.
" chlorstannate	"	1.6574	
" iodide	"	1.6666	
Phosphorus	"	2.1442	Gladstone & D
Resins: Aloes	red	1.619	Jamin.
Canada balsam	"	1.528	Wollaston.
Colophony	"	1.548	Jamin.
Copal	"	1.528	"
Mastic	"	1.535	Wollaston.
Peru balsam	D	1.593	Baden Powell.
Selenium, vitreous	A	2.612	Wood.
	B	2.680	
	C	2.729	
	D	2.93	
Silver bromide	D	2.253	Wernicke.
Silver chloride	"	2.061	
Silver iodide	"	2.182	
Sodalite blue	"	1.4827	Feusner.
Sodalite clear like water	"	1.4833	
Sodium chlorate	"	1.5150	Dussaud.
Spinel	"	1.7155	DesCloiseaux.
Strontium nitrate	"	1.5667	Fock.

INDEX OF REFRACTION.

TABLE 177. — Uniaxial Crystals.

Substance.	Line of spectrum.	Index of refraction. Ordinary ray.	Index of refraction. Extraordinary ray.	Authority.
ite (alum stone)	D	1.573	1.592	Levy & Lacroix.
inium arseniate	red	1.577	4.524	De Senarmont.
ite	D	2.5354	2.4959	Schrauf.
e	D	1.6390	1.6345	"
	D	1.6588	1.6784	DesCloiseaux.
	D	1.589 to 1.570	1.582 to 1.566	Various.
	D	1.560	1.581	Kohlrausch.
el	red	1.96	2.60	De Senarmont.
par	red	2.854	3.199	DesCloiseaux.
dum (ruby, sapphire, etc.)	red	1.767 to 1.769	1.759 to 1.762	"
se	green	1.667	1.723	"
ld (pure)	green	1.584	1.578	"
— 8° C.	D	1.309	1.313	Meyer.
se	D	1.719 to 1.722	1.717 to 1.720	DesCloiseaux.
	D	1.539	1.541	Kohlrausch.
site	D	1.717	1.515	Mallard.
ium arseniate	red	1.564	1.515	DesCloiseaux.
"	red	1.493	1.501	De Sernamont.
(red ore)	red	3.084	2.881	Fizeau.
n arseniate	D	1.459	1.467	Baker.
nitrate	D	1.587	1.336	Schrauf.
phosphate	D	1.446	2.452	Dufet.
nine sulphate	D	1.614	1.519	Martin.
one	D	1.997	2.093	Grubenman.
aline (colorless)	D	1.637	1.619	Heusser.
(different colors)	D	1.633 to 1.650	1.616 to 1.625	Jeroféjew.
(hyacinth)	red	1.92	1.97	De Senarmont.
"	D	1.924	1.968	Sanger.

TABLE 178. — Biaxial Crystals.

Substance.	Line of spectrum.	Index of refraction. Minimum.	Index of refraction. Intermediate.	Index of refraction. Maximum.	Authority.
site	D	1.8771	1.8823	1.8936	Arzruni.
rite	D	1.5693	1.5752	1.6130	Mülheims.
rin	D	1.5101	1.6812	1.6858	Glazebrook.
nite	D	1.5301	1.6816	1.6859	Rudberg.
e	red	1.6720	1.6779	1.6810	DesCloiseaux.
	D	1.636	1.637	1.648	Various.
	D	1.4467	1.4694	1.4724	Dufet.
r sulphate	D	1.5140	1.5368	1.5433	Kohlrausch.
m	D	1.5208	1.5228	1.5298	Mülheims.
muscovite)	D	1.5601	1.5936	1.5977	Pulfrich.
e	D	1.661	1.678	1.697	DesCloiseaux.
clase	D	1.5190	1.5237	1.5260	"
ium bichromate	D	1.7202	1.7380	1.8197	Dufet.
nitrate	D	1 3346	1.5056	1.5064	Schrauf.
sulphate	D	1·4932	1.4946	1.4980	Topsöe & Christiansen.
(cane)	D	1.5397	1.5667	1.5716	Calderon.
ar (rhombic)	D	1.9505	2.0383	2.2405	Schrauf.
(Brazilian)	D	1.6294	1.6308	1.6375	Mülheims.
(different kinds)	D	1.630 to 1.613	1.631 to 1.616	1.637 to 1.623	Various.
ulphate	D	1.4568	1.4801	1.4836	Topsöe & Christiansen.

INDEX OF REFRACTION.

Indices of Refraction relative to Air for Solutions of Salts and Acids.

Substance.	Density.	Temp. C.	Indices of refraction for spectrum lines.					Authority
			C	D	F	H_γ	H	
(a) SOLUTIONS IN WATER.								
Ammonium chloride	1.067	27°.05	1.37703	1.37936	1.38473	–	1.39336	Willigen.
" "	.025	29.75	.34850	.35050	.35515	–	.36243	"
Calcium chloride .	.398	25.65	.44000	.44279	.44938	–	.46001	"
" "	.215	22.9	.39411	.39652	.40206	–	.41078	"
" "	.143	25.8	.37152	.37369	.37876	–	.38666	"
Hydrochloric acid .	1.166	20.75	1.40817	1.41109	1.41774	–	1.42816	"
Nitric acid	.359	18.75	.39893	.40181	.40857	–	.41961	"
Potash (caustic) . .	.416	11.0	.40052	.40281	.40808	–	.41637	Fraunhof
Potassium chloride .	normal solution		.34087	.34278	.34719	1.35049	–	Bender.
" "	double normal		.34982	.35179	.35645	.35994	–	"
" "	triple normal		.35831	.36029	.36512	.36890	–	"
Soda (caustic) . .	1.376	21.6	1.41071	1.41334	1.41936	–	1.42872	Willigen.
Sodium chloride . .	.189	18.07	.37562	.37789	.38322	1.38746	–	Schutt.
" "	.109	18.07	.35751	.35959	.36442	.36823	–	"
" "	.035	18.07	.34000	.34191	.34628	.34969	–	"
Sodium nitrate . .	1.358	22.8	1.38283	1.38535	1.39134	–	1.40121	Willigen.
Sulphuric acid . .	.811	18.3	.43444	.43669	.44168	–	.44883	"
" "	.632	18.3	.42227	.42466	.42967	–	.43694	"
" "	.221	18.3	.36793	.37009	.37468	–	.38158	"
" "	.028	18.3	.33663	.33862	.34285	–	.34938	"
Zinc chloride . . .	1.359	26.6	1.39977	1.40222	1.40797	–	1.41738	"
" " . . .	.209	26.4	.37292	.37515	.38026	–	.38845	"
(b) SOLUTIONS IN ETHYL ALCOHOL.								
Ethyl alcohol . . .	0.789	25.5	1.35791	1.35971	1.36395	–	1.37094	Willigen.
" "	.932	27.6	.35372	.35556	.35986	–	.36662	"
Fuchsin (nearly saturated)	–	16.0	.3918	.398	.361	–	.3759	Kundt.
Cyanin (saturated) .	–	16.0	.3831	–	.3705	–	.3821	"

NOTE. — Cyanin in chloroform also acts anomalously; for example, Sieben gives fo
a 4.5 per cent. solution $\mu_A = 1.4593$, $\mu_B = 1.4695$, μ_F(green) $= 1.4514$, μ_G (blue) $= 1.455$
For a 9.9 per cent. solution he gives $\mu_A = 1.4902$, μ_F(green) $= 1.4497$, μ_G(blue) $= 1.459$

(c) SOLUTIONS OF POTASSIUM PERMANGANATE IN WATER.*

Wavelength in cms. × 10^6.	Spectrum line.	Index for 1 % sol.	Index for 2 % sol.	Index for 3 % sol.	Index for 4 % sol.	Wavelength in cms. × 10^6.	Spectrum line.	Index for 1 % sol.	Index for 2 % sol.	Index for 3 % sol.	Ind fo 4 %
68.7	B	1.3328	1.3342	–	1.3382	51.6	–	1.3368	1.3385	–	-
65.6	C	.3335	.3348	1.3365	.3391	50.0	–	.3374	.3383	1.3386	1.34
61.7	–	.3343	.3365	.3381	.3410	48.6	F	.3377	–	–	.34
59.4	–	.3354	.3373	.3393	.3426	48.0	–	.3381	.3395	.3398	.34
58.9	D	.3353	.3372	–	.3426	46.4	–	.3397	.3402	.3414	.34
56.8	–	.3362	.3387	.3412	.3445	44.7	–	.3407	.3421	.3426	.34
55.3	–	.3366	.3395	.3417	.3438	43.4	–	.3417	–	–	.34
52.7	E	.3363	–	–	–	42.3	–	.3431	.3442	.3457	.34
52.2	–	.3362	.3377	.3388	–	–	–	–	–	–	-

* According to Christiansen.

INDEX OF REFRACTION.

Indices of Refraction of Liquids relative to Air.

Substance.	Temp. C.	Index of refraction for spectrum lines.					Authority.
		C	D	F	H_γ	H	
Acetone	10°	1.3626	1.3646	1.3694	1.3732	–	Korten.
Almond oil	0	.4755	.4782	.4847	–	–	Olds.
Analin *	20	.5993	.5863	.6041	.6204	–	Weegmann.
Aniseed oil	21.4	.5410	.5475	.5647	–	–	Willigen.
" "	15.1	.5508	.5572	.5743	–	1.6084	Baden Powell.
Benzene †	10	1.4983	1.5029	1.5148	–	1.5355	Gladstone.
"	21.5	.4934	.4979	.5095	–	.5304	"
Bitter almond oil	20	.5391	–	.5623	.5775	–	Landolt.
Bromnaphtalin	20	.6495	.6582	.6819	.7041	.7289	Walter.
Carbon disulphide ‡	0	1.6336	1.6433	1.6688	1.6920	1.7175	Ketteler.
" "	20	.6182	.6276	.6523	.6748	.6994	"
" "	10	.6250	.6344	.6592	–	.7078	Gladstone.
" "	19	.6189	.6284	.6352	–	.7010	Dufet.
Cassia oil	10	.6007	.6104	.6389	–	.7039	Baden Powell.
" "	22.5	.5930	.6026	.6314	–	.6985	" "
Chinolin	20	1.6094	1.6171	1.6361	1.6497	–	Gladstone.
Chloroform	10	.4466	.4490	.4555	–	.4661	Gladstone & Dale.
"	30	–	.4397	–	–	.4561	" "
"	20	.4437	.4462	.4525	–	–	Lorenz.
Cinnamon oil	23.5	.6077	.6188	.6508	–	–	Willigen.
Ether	15	1.3554	1.3566	1.3606	–	1.3683	Gladstone & Dale.
"	15	.3573	.3594	.3641	–	.3713	Kundt.
Ethyl alcohol	0	.3677	.3695	.3739	.3773	–	Korten.
" "	10	.3636	.3654	.3698	.3732	–	"
" "	20	.3596	.3614	.3657	.3690	–	"
" "	15	.3621	.3638	.3683	–	.3751	Gladstone & Dale.
Glycerine	20	1.4706	–	1.4784	1.4828	–	Landolt.
Methyl alcohol	15	.3308	1.3326	.3362	–	.3421	Baden Powell.
Olive oil	0	.4738	.4763	.4825	–	–	Olds.
Rock oil	0	.4345	.4573	.4644	–	–	"
Turpentine oil	10.6	1.4715	1.4744	1.4817	–	1.4939	Fraunhofer.
" "	20.7	.4692	.4721	.4793	–	.4913	Willigen.
Toluene	20	.4911	.4955	.5070	.5170	–	Bruhl.
Water §	20	.3312	.3330	.3372	.3404	.3435	Means.

* Weegmann gives $\mu_D = 1.59668 - .000518\,t$. Knops gives $\mu_F = 1.61500 - .00056\,t$.

† Weegmann gives $\mu_D = 1.51474 - .000665\,t$. Knops gives $\mu_D = 1.51399 - .000644\,t$.

‡ Wüllner gives $\mu_C = 1.63407 - .00078\,t$; $\mu_F = 1.66908 - .00082\,t$; $\mu_h = 1.69215 - .00085\,t$.

§ Dufet gives $\mu_D = 1.33397 - 10^{-7}(125\,t + 20.6\,t^2 - .000435\,t^3 - .00115\,t^4)$ between 0° and 50°; and nearly the same variation with temperature was found by Ruhlmann, namely, $\mu_D = 1.33373 - 10^{-7}(20.14\,t^2 + .000494\,t^4)$.

INDEX OF REFRACTION.

Indices of Refraction of Gases and Vapors.

A formula was given by Biot and Arago expressing the dependence of the index of refraction of a gas on pressure and temperature. More recent experiments confirm their conclusions. The formula is $n_t - 1 = \frac{n_0 - 1}{1 + \alpha t} \frac{p}{760}$, where n_t is the index of refraction for temperature t, n_0 for temperature zero, α the coefficient of expansion of the gas with temperature, and p the pressure of the gas in millimetres of mercury. Taking the mean value, for air and white light, of $n_0 - 1$ as 0.0002936 and α as 0.00367 the formula becomes

$$n_t - 1 = \frac{.0002936}{1 + .00367\,t} \cdot \frac{P}{1.0136 \times 10^6} = \frac{.0002895}{1 + .00367} \frac{P}{10^6}$$

where P is the pressure in dynes per square centimetre, and t the temperature in degrees Centigrade.

(a) The following table gives some of the values obtained for the different Fraunhofer lines for air.

Spectrum line.	Index of refraction according to —			Spectrum line.	Index of refraction according to Kayser & Runge.
	Ketteler.	Lorenz.	Kayser & Runge.		
A	1.0002929	1.0002893	1.0002905	M	1.0002993
B	2935	2899	2911	N	3003
C	2938	2902	2914	O	3015
D	2947	2911	2922		
E	2958	2922	2933	P	1.0003023
				Q	3031
F	1.0002968	1.0002931	1.0002943	R	3043
G	2987	2949	2962		
H	3003	2963	2978	S	1.0003053
K	–	–	2980	T	3064
L	–	–	2987	U	3075

(b) The following are compiled mostly from a table published by Brühl (Zeits. für Phys. Chem. vol. 7, pp. 25–27). The numbers are from the results of experiments by Biot and Arago, Dulong, Jamin, Ketteler, Lorenz, Mascart, Chappius, Rayleigh, and Rivière and Prytz. When the number given rests on the authority of one observer the name of that observer is given. The values are for 0° Centigrade and 760 mm. pressure.

Substance.	Kind of light.	Indices of refraction and authority.	Substance.	Kind of light.	Indices of refraction and authority.
Acetone . . .	D	1.001079–1.001100	Hydrogen . .	white	1.000138–1.000143
Ammonia . .	white	1.000381–1.000385	" . .	D	1.000132 Burton.
" . .	D	1.000373–1.000379	Hydrogen sulphide . .	D	1.000644 Dulong.
Argon	D	1.000281 Rayleigh.		D	1.000623 Mascart.
Benzene . . .	D	1.001700–1.001823	Methane . . .	white	1.000443 Dulong.
Bromine . . .	D	1.001132 Mascart.	" . . .	D	1.000444 Mascart.
Carbon dioxide	white	1.000449–1.000450	Methyl alcohol .	D	1.000549–1.000623
" "	D	1.000448–1.000454	Methyl ether .	D	1.000891 Mascart.
Carbon disulphide . .	white	1.001500 Dulong.	Nitric oxide . .	white	1.000303 Dulong.
	D	1.001478–1.001485	" " . .	D	1.000297 Mascart.
Carbon monoxide . .	white	1.000340 Dulong.	Nitrogen . . .	white	1.000295–1.000300
	white	1.000335 Mascart.	" . . .	D	1.000296–1.000298
Chlorine . . .	white	1.000772 Dulong.	Nitrous oxide .	white	1.000503–1.000507
" . . .	D	1.000773 Mascart.	" " .	D	1.000516 Mascart.
Chloroform . .	D	1.001436–1.001464	Oxygen . . .	white	1.000272–1.000280
Cyanogen . .	white	1.000834 Dulong.	" . . .	D	1.000271–1.000272
" . .	D	1.000784–1.000825	Pentane . . .	D	1.001711 Mascart.
Ethyl alcohol .	D	1.000871–1.000885	Sulphur dioxide	white	1.000665 Dulong.
Ethyl ether . .	D	1.001521–1.001544	" "	D	1.000686 Ketteler.
Helium . . .	D	1.000036 Ramsay.	Water	white	1.000261 Jamin.
Hydrochloric acid . . .	white	1.000449 Mascart.	"	D	1.000249–1.000259
	D	1.000447 "			

According to Fresnel the amount of light reflected by the surface of a transparent medium $= \frac{1}{2}(A+B) = \frac{1}{2}\left\{\frac{\sin^2(i-r)}{\sin^2(i+r)} + \frac{\tan^2(i-r)}{\tan^2(i+r)}\right\}$; A is the amount polarized in the plane of incidence; B is that polarized perpendicular to this; i and r are the angles of incidence and refraction.

TABLE 182.—Light reflected when $i = 0°$ or Incident Light is Normal to Surface.

n.	$\frac{1}{2}(A+B)$.	n.	$\frac{1}{2}(A+B)$.	n.	$\frac{1}{2}(A+B)$.	n.	$\frac{1}{2}(A+B)$.
1.00	0.00	1.4	2.78	2.0	11.11	5.	44.44
1.02	0.01	1.5	4.00	2.25	14.06	5.83	50.00
1.05	0.06	1.6	5.33	2.5	18.37	10.	66.67
1.1	0.23	1.7	6.72	2.75	22.89	100.	96.08
1.2	0.83	1.8	8.16	3.	25.00	∞	100.00
1.3	1.70	1.9	9.63	4.	36.00		

TABLE 183.—Light reflected when n is near Unity or equals $1+dn$.

i.	A.	B.	$\frac{1}{2}(A+B)$.	$\frac{A-B}{A+B}$*
0°	1.000	1.000	1.000	0.0
5	1.015	.985	1.000	1.5
10	1.063	.939	1.001	6.2
15	1.149	.862	1.005	14.3
20	1.282	.752	1.017	26.0
25	1.482	.612	1.047	41.5
30	1.778	.444	1.111	60.0
35	2.221	.260	1.240	79.1
40	2.904	.088	1.496	94.5
45	4.000	.000	2.000	100.0
50	5.857	.176	3.016	94.5
55	9.239	1.081	5.160	79.1
60	16.000	4.000	10.000	60.0
65	31.346	12.952	22.149	41.5
70	73.079	42.884	57.981	26.0
75	222.85	167.16	195.00	14.3
80	1099.85	971.21	1035.53	6.2
85	17330.64	16808.08	17069.36	1.5
90	∞	∞	∞	0.0

TABLE 184.—Light reflected when $n = 1.55$.

i.	r.	A.	B.	dA.†	dB.†	$\frac{1}{2}(A+B)$.	$\frac{A-B}{A+B}$*
° ′	° ′						
0	0 0.0	4.65	4.65	0.130	0.130	4.65	0.0
5	3 13.4	4.70	4.61	.131	.129	4.65	1.0
10	6 25.9	4.84	4.47	.135	.126	4.66	4.0
15	9 36.7	5.09	4.24	.141	.121	4.66	9.1
20	12 44.8	5.45	3.92	.150	.114	4.68	16.4
25	15 49.3	5.95	3.50	.161	.105	4.73	25.9
30	18 49.1	6.64	3.00	.175	.094	4.82	37.8
35	21 43.1	7.55	2.40	.191	.081	4.98	51.7
40	24 30.0	8.77	1.75	.210	.066	5.26	66.7
45	27 8.5	10.38	1.08	.233	.049	5.73	81.2
50	29 37.1	12.54	0.46	.263	.027	6.50	92.9
55	31 54.2	15.43	0.05	.303	.007	7.74	99.3
60	33 58.1	19.35	0.12	.342	−.013	9.73	98.8
65	35 47.0	24.69	1.13	.375	−.032	12.91	91.2
70	37 19.1	31.99	4.00	.400	−.050	18.00	77.7
75	38 32.9	42.00	10.38	.410	−.060	26.19	61.8
80	39 26.8	55.74	23.34	.370	−.069	39 54	41.0
82 30	39 45.9	64.41	34.04	.320	−.067	49.22	30.8
85 0	39 59.6	74.52	49.03	.250	−.061	61.77	20.6
86 0	40 3.6	79.02	56.62	.209	−.055	67.82	16.5
87 0	40 6.7	83.80	65.32	.163	−.046	74.56	12.4
88 0	40 8.9	88.88	75.31	.118	−.036	82.10	8.3
89 0	40 10.2	94.28	86.79	.063	−.022	90.54	4.1
90 0	40 10.7	100.00	100.00	.000	−.000	100.00	0.0

Angle of total polarization = 57° 10′.3, A = 16.99.

* This column gives the degree of polarization.

† Columns 5 and 6 furnish a means of determining A and B for other values of n. They represent the change in these quantities for a change of n of 0.01.

Taken from E. C. Pickering's "Applications of Fresnel's Formula for the Reflection of Light."

TABLE 185.

REFLECTION OF METALS.

Perpendicular Incidence and Reflection.

The numbers give the per cents of the incident radiation reflected.

Wave-length, μ.	Silver-backed Glass.	Mercury-backed Glass.	Mach's Magnalium. $6Al+3Mg$.	Brandes-Schlinemann Alloy. $32Cu+34Sn+29Ni+5Fe$.	Ross' Speculum Metal. $68.2Cu+31.8Sn$.	Nickel. *Electrolytically Deposited.*	Copper. *Electrolytically Deposited.*	Steel. *Unitempered.*	Copper. *Commercially Pure.*	Platinum. *Electrolytically Deposited.*	Gold. *Electrolytically Deposited.*	Brass. (*Trowbridge*).	Silver. *Chemically Deposited.*
.251	–	–	67.0	35.8	29.9	37.8	–	32.9	25.9	33.8	38.8	–	34.1
.288	–	–	70.6	37.1	37.7	42.7	–	35.0	24.3	38.8	34.0	–	21.2
.305	–	–	72.2	37.2	41.7	44.2	–	37.2	25.3	39.8	31.8	–	9.1
.316	–	–	–	–	–	–	–	–	–	–	–	–	4.2
.326	–	–	75.5	39.3	–	45.2	–	40.3	24.9	41.4	28.6	–	14.6
.338	–	–	–	–	–	46.5	–	–	–	–	–	–	55.5
.357	–	–	81.2	43.3	51.0	48.8	–	45.0	27.3	43.4	27.9	–	74.5
.385	–	–	83.9	44.3	53.1	49.6	–	47.8	28.6	45.4	27.1	–	81.4
.420	–	–	83.3	47.2	56.4	56.6	–	51.9	32.7	51.8	29.3	–	86.6
.450	85.7	72.8	83.4	49.2	60.0	59.4	48.8	54.4	37.0	54.7	33.1	–	90.5
.500	86.6	70.9	83.3	49.3	63.2	60.8	53.3	54.8	43.7	58.4	47.0	–	91.3
.550	88.2	71.2	82.7	48.3	64.0	62.6	59.5	54.9	47.7	61.1	74.0	–	92.7
.600	88.1	69.9	83.0	47.5	64.3	64.9	83.5	55.4	71.8	64.2	84.4	–	92.6
.650	89.1	71.5	82.7	51.5	65.4	66.6	89.0	56.4	80.0	66.5	88.9	–	94.7
.700	89.6	72.8	83.3	54.9	66.8	68.8	90.7	57.6	83.1	69.0	92.3	–	95.4
.800	–	–	84.3	63.1	–	69.6	–	58.0	88.6	70.3	94.9	–	96.8
1.0	–	–	84.1	69.8	70.5	72.0	–	63.1	90.1	72.9	–	–	97.0
1.5	–	–	85.1	79.1	75.0	78.6	–	70.8	93.8	77.7	97.3	–	98.2
2.0	–	–	86.7	82.3	80.4	83.5	–	76.7	95.5	80.6	96.8	91.0	97.8
3.0	–	–	87.4	85.4	86.2	88.7	–	83.0	97.1	88.8	–	93.7	98.1
4.0	–	–	88.7	87.1	88.5	91.1	–	87.8	97.3	91.5	96.9	95.7	98.5
5.0	–	–	89.0	87.3	89.1	94.4	–	89.0	97.9	93.5	97.0	95.9	98.1
7.0	–	–	90.0	88.6	90.1	94.3	–	92.9	98.3	95.5	98.3	97.0	98.5
9.0	–	–	90.6	90.3	92.2	95.6	–	92.9	98.4	95.4	98.0	97.8	98.7
11.0	–	–	90.7	90.2	92.9	95.9	–	94.0	98.4	95.6	98.3	96.6	98.8
14.0	–	–	92.2	90.3	93.6	97.2	–	96.0	97.9	96.4	97.9	–	98.3

Based upon the work of Hagen and Rubens, Ann. der Phys. (1) 352, 1900; (8) 1, 1902; (11) 873, 1903.
Taken partly from Landolt-Börnstein-Meyerhoffer's Physikalisch-chemische Tabellen.

Further references:

Conroy, Proc. Roy. Soc. 35, 26, 1883.
De la Provastaye and P. Desains, Ann. Chim. Phys. (3) 30, 276, 1850.
Langley, Phil. Mag. (5) 27, 10, 1889.
Mach and Schumann, Wien. Ber. 108, 135, 1899.
Nichols, Wied. Ann. 60, 401, 1897.
Nutting, Phys. Rev. 13, 193, 1901.
Paschen, Ann. der Phys. 4, 304, 1901.
Rayleigh, Proc. Roy. Soc. 41, 274, 1886.
Rubens, Wied. Ann. 37, 249, 1889.
Trowbridge, Wied. Ann. 65, 595, 1898.

TRANSMISSIBILITY FOR RADIATION OF JENA GLASSES.

TABLE 186.

Coefficients, a, in the formula $I_t = I_0 a^t$, where I_0 is the Intensity before, and I_t after, transmission through the thickness t, expressed in centimetres. Deduced from observations by Müller, Vogel, and Rubens as quoted in Hovestadt's Jena Glass (English translation).

Type of Glass.	Coefficient of transmission, a.									
$\lambda =$	.375 μ	390 μ	.400 μ	.434 μ	.436 μ	.455 μ	.477 μ	.503 μ	.580 μ	.677 μ
O 340, Ord. light flint	.388	.456	.614	.569	.680	.834	.880	.880	.878	.939
O 102, H'vy silicate flint	–	.025	.463	.502	.566	.663	.700	.782	.828	.794
O 93, Ord. " "	–	–	–	–	.714	.807	.899	.871	.903	.943
O 203, " " crown	.583	.583	.695	.667	.806	.822	.860	.872	.872	.903
O 598, (Crown)	–	–	–	–	.797	.770	.771	.776	.818	.860

$\lambda =$	0.7 μ	0.95 μ	1.1 μ	1.4 μ	1.7 μ	2.0 μ	2.3 μ	2.5 μ	2.7 μ	2.9 μ	3.1 μ
S 204, Borate crown	1.0	.90	.55	.37	.21	.12	.025	.02	.04	.03	
S 179, Med. phosp. cr.	–	.82	.61	.37	.17	.018	.08	.25	.05		
O 1143, Dense, bor. sil. cr.	–	–	.74	–	.61	.50	.33	.18	.034	.06	.021
O 1092, Crown	.91	.67	.61	.90	.91	.41	.14	.033	.006	.07	.043
O 1151, "	.82	–	.91	.90	.82	.55	.33	.10	.055	.04	.010
O 451, Light flint	1.0	–	.91	–	.82	.61	.45	.17	.083	.002	.019
O 469, Heavy "	1.0	–	.82	–	.91	.82	.82	.74	.33	.017	.010
O 500, " "	1.0	–	1.0	–	1.0	–	1.0	.90	.45	.050	.019
S 163, " "	1.0	–	.82	–	.91	–	.91	–	.55	.083	.062

TABLE 187.

Note: With the following data, t must be expressed in millimetres; i. e. the figures as given give the transmissions for thickness of 1 mm.

No. and Type of Glass.	Wave-length in μ.											
	Visible Spectrum.							Ultra-violet Spectrum.				
	.644 μ	.578 μ	.546 μ	.509 μ	.480 μ	.436 μ	.405 μ	.384 μ	.361 μ	.340 μ	.332 μ	.309 μ	.280 μ
F 3815 Dark neutral	.35	.35	.37	.35	.34	.30	.15	.06					
F 4512 Red filter	.94	.05											
F 2745 Copper ruby	.72	.39	.47	.47	.45	.43	.43						
F 4313 Dark yellow	.98	.97	.93	.83	.09								
F 4351 Yellow	.98	.97	.96	.93	.44	.15							
F 4937 Bright yellow	1.0	1.0	1.0	.99	.74	.40	.31	.28	.22	.18	.14	.06	
F 4930 Green filter	.17	.50	.64	.62	.44								
F 3873 Blue filter	–	–	–	.18	.50	.73	.69	.59	.36	.10			
F 3654 Cobalt glass, transparent for outer red	–	–	–	.15	.44	.85	1.0	1.0	1.0	1.0	1.0	.58	
F 3653 Blue, ultraviolet	–	–	–	–	.11	.65	1.0	1.0	1.0	1.0	1.0	.81	.18
F 3728 Didymium, str'g bands	.99	.72	.99	.96	.95	.96	.99	.99	.89	.89	.77	.54	

This and the following table are taken from Jenaer Glas für die Optik, Liste 751, 1909.

TABLE 188. — Transmissibility of Jena Ultra-violet Glasses.

No. and Type of Glass.	Thickness.	0.397 μ	0.383 μ	0.361 μ	0.346 μ	0.325 μ	0.309 μ	0.280 μ
UV 3199 Ultra-violet	1 mm.	1.00	1.00	1.00	1.00	1.00	0.95	0.56
" "	2 mm.	0.99	0.99	0.99	0.97	0.90	0.57	
" "	1 dm.	0.95	0.95	0.89	0.70	0.36		
UV 3248 "	1 mm.	1.00	1.00	1.00	1.00	0.98	0.91	0.35
" "	2 mm.	0.98	0.98	0.98	0.92	0.78	0.38	
" "	1 dm.	0.96	0.87	0.79	0.45	0.08		

TABLE 189.

TRANSMISSIBILITY FOR RADIATION.

Transmissibility of the Various Substances of Tables 166 to 175.

Alum: Ordinary alum (crystal) absorbs the infra-red.
Metallic reflection at 9.05μ and 30 to 40μ.

Rock-salt: Rubens and Trowbridge (Wied. Ann. 65, 1898) give the following transparencies for a 1 cm. thick plate in %:

λ	9	10	12	13	14	15	16	17	18	19	20.7	23.7μ
%	99.5	99.5	99.3	97.6	93.1	84.6	66.1	51.6	27.5	9.6	0.6	0.

Pflüger (Phys. Zt. 5. 1904) gives the following for the ultra-violet, same thickness: 280$\mu\mu$, 95.5%; 231, 86%; 210, 77%; 186, 70%.
Metallic reflection at 0.110μ, 0.156, 51.2, and 87μ.

Sylvine: Transparency of a 1 cm. thick plate (Trowbridge, Wied. Ann. 60, 1897).

λ	9	10	11	12	13	14	15	16	17	18	19	20.7	23.7μ
%	100.	98.8	99.0	99.5	99.5	97.5	95.4	93.6	92.	86.	76.	58.	15.

Metallic reflection at 0.114μ, 0.161, 61.1, 100.

Fluorite: Very transparent for the ultra-violet nearly to 0.1μ.
Rubens and Trowbridge give the following for a 1 cm. plate (Wied. Ann. 60, 1897):

λ	8μ	9	10	11	12μ
%	84.4	54.3	16.4	1.0	0

Metallic reflection at 24μ, 31.6, 40μ.

Iceland Spar: Merritt (Wied. Ann. 55, 1895) gives the following values of k in the formula $i = i_0 e^{-kd}$ (d in cm.):
For the ordinary ray:

λ	1.02	1.45	1.72	2.07	2.11	2.30	2.44	2.53	2.60	2.65	2.74μ
k	0.0	0.0	0.03	0.13	0.74	1.92	3.00	1.92	1.21	1.74	2.36

λ	2.83	2.90	2.95	3.04	3.30	3.47	3.62	3.80	3.98	4.35	4.52	4.83μ
k	1.32	0.70	1.80	4.71	22.7	19.4	9.6	18.6	∞	6.6	14.3	6.1

For the extraordinary ray:

λ	2.49	2.87	3.00	3.28	3.38	3.59	3.76	3.90	4.02	4.41	4.67μ
k	0.14	0.08	0.43	1.32	0.89	1.79	2.04	1.17	0.89	1.07	2.40

λ	4.91	5.04	5.34	5.50μ
k	1.25	2.13	4.41	12.8

Quartz: Very transparent to the ultra-violet; Pflüger gets the following transmission values for a plate 1 cm. thick: at 0.222μ, 94.2%; 0.214, 92; 0.203, 83.6; 0.186, 67.2%.
Merritt (Wied. Ann. 55, 1895) gives the following values for k (see formula under Iceland Spar):
For the ordinary ray:

λ	2.72	2.83	2.95	3.07	3.17	3.38	3.67	3.82	3.96	4.12	4.50μ
k	0.20	0.47	0.57	0.31	0.20	0.15	1.26	1.61	2.04	3.41	7.30

For the extraordinary ray:

λ	2.74	2.89	3.00	3.08	3.26	3.43	3.52	3.59	3.64	3.74	3.91	4.19	4.36μ
k	0.0	0.11	0.33	0.26	0.11	0.51	0.76	1.88	1.83	1.62	2.22	3.35	8.0

For $\lambda > 7$ μ, becomes opaque, metallic reflection at 8.50μ, 9.02, 20.75–24.4μ, then transparent again.

The above are taken from Kayser's "Handbuch der Spectroscopie," vol. iii.

TRANSMISSIBILITY FOR RADIATION.

TABLE 190. — Color Screens.

The following light-filters are quoted from Landolt's "Das optische Drehungsvermögen, etc." 1898. Although only the potassium salt does not keep well it is perhaps safer to use freshly prepared solutions.

Color.	Thickness. mm.	Water solutions of	Grammes of substance in 100 c.cm.	Optical centre of band. μ	Transmission.
Red	20	Crystal-violet, 5BO	0.005	0.6659	begins about 0.718μ. ends sharp at 0.639μ.
"	20	Potassium monochromate	10.		
Yellow	20	Nickel-sulphate, $NiSO_4.7aq.$	30.	0.5919	0.614–0.574μ,
"	15	Potassium monochromate	10.		
"	15	Potassium permanganate	0.025		
Green	20	Copper chloride, $CuCl_2.2aq.$	60.	0.5330	0.540–0.505μ
"	20	Potassium monochromate	10.		
Bright blue	20	Double-green, SF	0.02	0.4885	0.526–0.494 and 0.494–0.458μ
	20	Copper-sulphate, $CuSO_4.5aq.$	15.		
Dark blue	20	Crystal-violet, 5BO	0.005	0.4482	0.478–0.410μ
	20	Copper sulphate, $CuSO_4.5aq.$	15.		

TABLE 191. — Color Screens.

The following list is condensed from Wood's Physical Optics, 2nd edition:

Methyl violet, 4R· (Berlin Anilin Fabrik) very dilute, and nitroso-dimethyl-aniline transmits 0.365μ.

Methyl violet + chinin-sulphate (separate solutions), the violet solution made strong enough to blot out 0.4359μ, transmits 0.4047 and 0.4048, also faintly 0.3984.

Cobalt glass + aesculin solution transmits 0.4359μ.

Guinea green B extra (Berlin) + chinin sulphate transmits 0.4916μ.

Neptune green (Bayer, Elberfeld) + chrysoidine. Dilute the latter enough to just transmit 0.5790 and 0.5461; then add the Neptune green until the yellow lines disappear.

Chrysoidine + eosine transmits 0.5790μ. The former should be dilute and the eosine added until the green line disappears.

Silver chemically deposited on a quartz plate is practically opaque except to the ultra-violet region 0.3160–0.3260 where 90% of the energy passes through. The film should be of such thickness that a window backed by a brilliantly lighted sky is barely visible.

In the following those marked with a * are transparent to a more or less degree to the ultra-violet:

*Cobalt chloride: solution in water, — absorbs 0.50–.53μ; addition of $CaCl_2$ widens the band to 0.47–.50. It is exceedingly transparent to the ultra-violet down to 0.20. If dissolved in methyl alcohol + water, absorbs 0.50–.53 and everything below 0.35. In methyl alcohol alone 0.485–0.555 and below 0.40μ.

Copper chloride: in ethyl alcohol absorbs above 0.585 and below 0.535; in alcohol + 50% water, above 0.595 and below 0.37μ.

Neodymium salts are useful combined with other media, sharpening the edges of the absorption bands. In solution with bichromate of potash, transmits 0.535–.565 and above 0.60μ, the bands very sharp (a useful screen for photographing with a visually corrected objective).

Praesodymium salts: three strong bands at 0.482, .468, .444. In strong solutions they fuse into a sharp band at 0.435–.485μ. Absorption below 0.34.

Picric acid absorbs 0.36–.42μ, depending on the concentration.

Potassium chromate absorbs 0.40–.35, 0.30–.24, transmits 0.23μ.

*Potassium permanganate: absorbs 0.555–.50, transmits all the ultra-violet.

Chromium chloride: absorbs above 0.57, between 0.50 and .39, and below 0.33μ. These limits vary with the concentration.

Aesculin: absorbs below 0.363μ, very useful for removing the ultra-violet.

*Nitroso-dimethyl-aniline: very dilute aqueous solution absorbs 0.49–.37 and transmits all the ultra-violet.

Very dense cobalt glass + dense ruby glass or a strong potassium bichromate solution cuts off everything below 0.70 and transmits freely the red.

Iodine: saturated solution in CS_2 is opaque to the visible and transparent to the infra-red.

TRANSMISSIBILITY FOR RADIATION.

Color Screens. Jena Glasses.

	Kind of Glass.	Maker's No.	Color.	Region Transmitted.	Thickness. mm.
1	Copper-ruby	2728	Deep red	Only red to 0.6μ	1.7
1a	Gold-ruby	459^{III}	Red	Red, yellow; in thin layers also blue and violet.	
2	Uranium	454^{III}	Bright yellow	Red, yellow, green to E_b; in thin layer also blue	16.
2a	"	455^{III}	Bright yellow, fluoresces.		
3	Nickel	440^{III}	Bright yellow-brown	Red, yellow, green (weakened), blue (very weakened)	11.
4	Chromium	414^{III}	Yellow-green	Yellowish-green	10.
4a	"	433^{III}	Greenish-yellow	Red, green; from 0.65–.50μ	5.
4b	Green copper	431^{III}	Green	Green, yellow, some red and blue	2–3
5	Chromium	432^{III}	Yellow-green	Yellowish-green, some red	2.5
6	Copper chromium	436^{III}	Grass-green	Green	5.
7	Green-filter	437^{III}	Dark green	Green (in thin sheets some blue)	5.
8	" "	438^{III}	" "	Green	
10	Copper	2742	Blue, as $CuSO_4$	Green, blue, violet	5–12
11	Blue-violet	447^{III}	Blue, as cobalt glass	Blue, violet	5.
"	" "	"	" " " "	Blue, violet, blue-green (weakened), *no red*	2–5
12	Cobalt	424^{III}	Blue	Blue, violet, extreme red	4–5
13	Nickel	450^{III}	Dark violet	Violet (G–H), extreme red	6.
14	Violet	452^{III}	" "	Violet (G–H), some weakened	7.
15	Gray	444^{III}	Gray, no recognizable color	All parts of the spectrum weakened	0.1–8
16	"	445^{III}			0.1–3

See "Über Farbgläser für wissenschaftliche und technische Zwecke," by Zsigmondy, Z. für Instrumentenkunde, 21, 1901 (from which the above table is taken), and "Über Jenenser Lichtfilter," by Grebe, same volume.

(The following notes are quoted from Everett's translation of the above in the English edition of Hovestadt's "Jena Glass.")

Division of the spectrum into complementary colors:

1st by 2728 (deep red) and 2742 (blue, like copper sulphate).
2nd by 454^{III} (bright yellow) and 447^{III} (blue, like cobalt glass).
3rd by 433^{III} (greenish-yellow) and 424^{III} (blue).

Thicknesses necessary in above: 2728, 1.6–1.7 mm.; 2742, 5; 454^{III}, 16; 447^{III}, 1.5–2.0; 433^{III}, 2.5–3.5; 424^{III}, 3 mm.

Three-fold division into red, green and blue (with violet):

2728, 1.7 mm.; 414^{III}, 10 mm.; 447^{III}, 1.5 mm., or by
2728, 1.7 mm.; 436^{III}, 2.6 mm.; 447^{III}, 1.8 mm.

Grebe found the three following glasses specially suited for the additive methods of three-color projection:

2745, red; 438^{III}, green; 447^{III}, blue violet;

corresponding closely to Young's three elementary color sensations.

Most of the Jena glasses can be supplied to order, but the absorption bands vary somewhat in different meltings.

See also "Atlas of Absorption Spectra," Uhler and Wood, Carnegie Institution Publications, 1907.

TABLE 193.—Tartaric Acid; Camphor; Santonin; Santonic Acid; Cane Sugar.

A few examples are here given showing the effect of wave-length on the rotation of the plane of polarization. The rotations are for a thickness of one decimetre of the solution. The examples are quoted from Landolt & Börnstein's "Phys. Chem. Tab." The following symbols are used:—

p = number grammes of the active substance in 100 grammes of the solution.
c = " " solvent " " " "
q = " " active " " cubic centimetre "

Right-handed rotation is marked +, left-handed —.

Line of spectrum.	Wave-length according to Ångström in cms. × 10^8.	Tartaric acid,* CuH_6O_6, dissolved in water. q = 50 to 95, temp. = 24° C.	Camphor,* $C_{10}H_{16}O$, dissolved in alcohol. q = 50 to 95, temp. = 22.9° C.	Santonin,† $C_{15}H_{18}O_3$, dissolved in chloroform. q = 75 to 96.5, temp. = 20° C.
B	68.67			— 140°.1 + 0.2085 q
C	65.62	+ 2°.748 + 0.09446 q	38°.549 — 0.0852 q	— 149.3 + 0.1555 q
D	58.92	+ 1.950 + 0.13030 q	51.945 — 0.0964 q	— 202.7 + 0.3086 q
E	52.69	+ 0.153 + 0.17514 q	74.331 — 0.1343 q	— 285.6 + 0.5820 q
b_1	51.83	– –	– –	— 302.38 + 0.6557 q
b_2	51.72	— 0.832 + 0.19147 q	79.348 — 0.1451 q	– –
F	48.61	— 3.598 + 0.23977 q	99.601 — 0.1912 q	— 365.55 + 0.8284 q
e	43.83	— 9.657 + 0.31437 q	149.696 — 0.2346 q	— 534.98 + 1.5240 q

	Santonin,† $C_{15}H_{18}O_3$, * dissolved in alcohol. c = 1.782. temp. = 20° C.	Santonin,† $C_{15}H_{18}O_3$, dissolved in alcohol. c = 4.046. temp. = 20° C.	Santonin,† $C_{15}H_{18}O_3$, dissolved in chloroform c = 3.1–30.5. temp. = 20° C.	Santonic acid,† $C_{15}H_{20}O_4$, dissolved in chloroform. c = 27.192. temp. = 20° C.	Cane sugar,‡ $C_{12}H_{22}O_{11}$, dissolved in water. p = 10 to 30.
B	68.67	— 110.4°	442°	484°	— 49°	47°.56
C	65.62	— 118.8	504	549	— 57	52.70
D	58.92	— 161.0	693	754	— 74	60.41
E	52.69	— 222.6	991	1088	— 105	84.56
b_1	51.83	— 237.1	1053	1148	— 112	–
b_2	51.72	–	–	–	–	87.88
F	48.61	— 261.7	1323	1444	— 137	101.18
e	43.83	— 380.0	2011	2201	— 197	–
G	43.07	–	–	–	–	131.96
g	42.26	–	2381	2610	— 230	–

* Arndtsen, "Ann. Chim. Phys." (3) 54, 1858.
† Narini, "R. Acc. dei Lincei," (3) 13, 1882.
‡ Stefan, "Sitzb. d. Wien. Akad." 52, 1865.

TABLE 194.—Sodium Chlorate; Quartz.

Sodium chlorate (Guye, C. R. 108, 1889).			Quartz (Soret & Sarasin, Arch. de Gen. 1882, or C. R. 95, 1882).*					
Spectrum line.	Wave-length.	Temp. C.	Rotation per mm.	Spectrum line.	Wave-length.	Rotation per mm.	Spectrum line.	Wave-length.	Rotation per mm.
a	71.769	15°.0	2°.068	A	76.04	12°.668	Cd_9	36.090	63°.628
B	67.889	17.4	2.318	a	71.836	14.304	N	35.818	64.459
C	65.073	20.6	2.599	B	68.671	15.746	Cd_{10}	34.655	69.454
D	59.085	18.3	3.104				O	34.406	70.587
E	53.233	16.0	3.841	C	65.621	17.318			
F	48.912	11.9	4.587	D_1	58.951	21.684	Cd_{11}	34.015	72.448
G	45.532	10.1	5.331	D_2	58.891	21.727	P	33.600	74.571
G	42.834	14.5	6.005				Q	32.858	78.579
H	40.714	13.3	6.754	E	52.691	27.543	Cd_{12}	32.470	80.459
L	38.412	14.0	7.654	F	48.607	32.773			
M	37.352	10.7	8.100	G	43.072	42.604	R	31.798	84.972
N	35.818	12.9	8.861				Cd_{17}	27.467	121.052
P	33.931	12.1	9.801	h	41.012	47.481	Cd_{18}	25.713	143.266
Q	32.341	11.9	10.787	H	39.681	51.193	Cd_{23}	23.125	190.426
R	30.645	13.1	11.921	K	39.333	52.155			
T	29.918	12.8	12.424				Cd_{24}	22.645	201.824
Cd_{17}	28.270	12.2	13.426	L	38.196	55.625	Cd_{25}	21.935	220.731
Cd_{18}	25.038	11.6	14.965	M	37.262	58.894	Cd_{26}	21.431	235.972

* The paper is quoted from a paper by *Ketteler in* "Wied. Ann." vol. 21, p. 444. The wave-lengths are for the Fraunhofer lines, *Ångström's values for the ultra violet sun*, and Cornu's values for the cadmium lines.

TABLE 195.

NEWTON'S RINGS.

Newton's Table of Colors.

The following table gives the thickness in millionths of an inch, according to Newton, of a plate of air, water, and glass corresponding to the different colors in successive rings commonly called colors of the first, second, third, etc., orders.

Order.	Color for reflected light.	Color for transmitted light.	Thickness in millionths of an inch for — Air.	Water.	Glass.
I.	Very black	—	0.5	0.4	0.2
	Black	White	1.0	0.75	0.9
	Beginning of black	—	2.0	1.5	1.3
	Blue	Yellowish red	2.4	1.8	1.5
	White	Black	5.2	3.9	3.4
	Yellow	Violet	7.1	5.3	4.6
	Orange	—	8.0	6.0	4.2
	Red	Blue	9.0	6.7	5.8
II.	Violet	White	11.2	3.4	7.2
	Indigo	—	12.8	9.6	8.4
	Blue	Yellow	14.0	10.5	9.0
	Green	Red	15.1	11.3	9.7
	Yellow	Violet	16.3	12.2	10.4
	Orange	—	17.2	13.0	11.3
	Bright red	Blue	18.2	13.7	11.8
	Scarlet	—	19.7	14.7	12.7
III.	Purple	Green	21.0	15.7	13.5
	Indigo	—	21.1	17.6	14.2
	Blue	Yellow	23.2	17.5	15.1
	Green	Red	25.2	18.6	16.2
	Yellow	Bluish green	27.1	20.3	17.5
	Red	—	29.0	21.7	18.7
	Bluish red	—	32.0	24.0	20.7
IV.	Bluish green	—	24.0	25.5	22.0
	Green	Red	35.3	26.5	22.7
	Yellowish green	—	36.0	27.0	23.2
	Red	Bluish green	40.3	30.2	26.0
V.	Greenish blue	Red	46.0	34.5	39.7
	Red	—	52.5	39.4	34.0
VI.	Greenish blue	—	58.7	46	38.0
	Red	—	65.0	48.7	42.0
VII.	Greenish blue	—	72.0	53.2	45.8
	Reddish white	—	71.0	57.7	49.4

The above table has been several times revised both as to the colors and the numerical values. Professors Reinold and Rucker, in their investigations on the measurement of the thickness of soap films, found it necessary to make new determinations. They give a shorter series of colors, as they found difficulty in distinguishing slight differences of shade, but divide each color into ten parts and tabulate the variation of thickness in terms of the tenth of a color band. The position in the band at which the thickness is given and the order of color are indicated by numerical subscripts. For example: $R_{1\,5}$ indicates the red of the first order and the fifth tenth from the edge furthest from the red edge of the spectrum. The thicknesses are in millionths of a centimetre.

Order.	Color.	Position.	Thickness.	Order.	Color.	Position.	Thickness.	Order.	Color.	Position.	Thickness.
I.	Red *	$R_{1\,5}$	28.4		Red *	$R_{3\,5}$	76.5	VI.	Green	$G_{6\,0}$	141.0
II.	Violet	$V_{2\,5}$	30.5		Bluish red *	$BR_{3\,5}$	81.5		Green *	$G_{6\,5}$	147.9
	Blue	$B_{2\,5}$	35.3	IV.	Green	$G_{4\,0}$	84.1		Red	$R_{6\,0}$	154.8
	Green	$G_{2\,5}$	40.9		"	$G_{4\,5}$	89.3		Red *	$R_{6\,5}$	162.7
	Yellow *	$Y_{2\,5}$	45.4		Yellow green *	$YG_{4\,5}$	96.4	VII.	Green	$G_{7\,0}$	170.5
	Orange *	$O_{2\,5}$	49.1		Red *	$R_{4\,5}$	105.2		Green *	$G_{7\,5}$	178.7
	Red	$R_{2\,5}$	52.2						Red	$R_{7\,0}$	186.9
III.	Purple	$P_{3\,5}$	55.9						Red *	$R_{7\,5}$	193.6
	Blue	$B_{3\,0}$	57.7	V.	Green	$G_{5\,0}$	111.9	VIII.	Green	$G_{8\,0}$	200.4
	Blue *	$B_{3\,5}$	60.3		Green *	$G_{5\,5}$	118.8		Red	$R_{8\,0}$	211.5
	Green	$G_{3\,5}$	65.6		Red	$R_{5\,0}$	126.0				
	Yellow *	$Y_{3\,5}$	71.0		Red *	$R_{5\,5}$	133.5				

* The colors marked are the same as the corresponding colors in Newton's table.

CONDUCTIVITY FOR HEAT.

The coefficient k is the quantity of heat in small calories which is transmitted per second through a plate one centimetre thick per square centimetre of its surface when the difference of temperature between the two faces of the plate is one degree Centigrade. The coefficient k is found to vary with the absolute temperature of the plate, and is expressed approximately by the equation $k_t = k_o(1 + \alpha t)$. In the table k_o is the value of k_t for 0° C., t the temperature Centigrade, and α a constant.

Substance.	t	k_t	α	Authority.
Aluminum	0	0.3435	.0005356	1
	100	.3619		
Antimony	0	.0442	—.001041	1
	100	.0396		
Bismuth	0	.0177	—.000735	1
	100	.0164		
Brass (yellow)	0	.2041	.002445	1
	100	.2540		
" (red)	0	.2460	.001492	1
	100	.2827		
Cadmium	0	.2200	—.000705	1
	100	.2045		
Constantin	18	.5402	–	2
60Cu+40Ni	100	.6405	–	2
Copper	0	.7189	.000051	1
	100	.7226		
German silver	0	.0700	.002670	1
	100	.0887		
Iron	0	.1665	—.000228	1
	100	.1627		
" (wrought)*	0	.2070	–	3
	100	.1567		
Lead	0	.0836	—.000861	1
	100	.0764		
Mercury	0	.0148	–	4
	50	.0189		
Magnesium	0–100	.3760	.000000	1
Manganin				
84Cu+4Ni+	18	.5186	–	2
12Mn	100	.6310	–	2
Nickel	18	.1420	–	2
Palladium	18	.1683	–	2
Platinum	18	.1664	–	2
	100	.1733	–	2
Steel (hard)	–	.0620	–	5
" (soft)	–	.1110	–	5
Silver	0	1.0960	–	4
Tin	0	0.1528	—.000687	1
	100	.1423		
Wood's alloy	–	.0319	–	4
Zinc	18	.2653	–	2

Substance.	t	k_t	Authority.
Carborundum	–	.00050	12
Slate	–	.0036	11
Soil dry	–	.00033	11
" wet	–	.0016	11
Diatomic earth	–	.00013	12
Fire-brick	–	.00028	12
Granite, from	–	.00510	6
Granite, to	–	.00550	6
Lime	–	.00029	12
Magnesia, from	–	.00016	12
Magnesia, to	–	.00045	12
Marbles, limestone, calcite, compact dolomite, from	–	.00470	6
Marbles, limestone, calcite, compact dolomite, to	–	.00560	6
Micaceous flagstone: along cleavage	–	.00632	6
Micaceous flagstone: across cleavage	–	.00441	6
Paraffine	–	.00014	8
Paraffine	0	.00023	9
Paraffine	100	.00168	9
Pasteboard	–	.00045	8
Plaster of Paris	–	.00070	11
" " " powder	–	.0026	11
Quartz	–	.00036	12
Sand (white dry)	–	.00093	6
Sandstone and hard grit, from	–	.00545	6
Sandstone and hard grit, to (dry)	–	.00565	6
Sawdust	–	.00012	8
Serpentine (Cornwall red)	–	.00441	6
Slate: along cleavage, from	–	.00550	6
Slate: along cleavage, to	–	.00650	6
Slate: across cleavage, from	–	.00315	6
Slate: across cleavage, to	–	.00360	6
Snow, compact layers	–	.00051	7
Strawboard	–	.00033	8
Vulcanite	–	.00087	10
Vulcanized rubber (soft), from	–	.00034	6
Vulcanized rubber (soft), to	–	.00054	6
Wax (bees)	–	.00009	8
Wood, fir: parallel to axis	–	.00030	8
Wood, fir: perpendicular to axis	–	.00009	8

1 Lorenz. 4 H. F. Weber. 6 H. L. & D.‡ 8 G. Forbes. 10 Stefan.
2 J + Dt. 5 Kohlrausch. 7 Hjeltström. 9 R. Weber. 11 Lees-Chorlton.
3 J. Forbes. 12 Hutton-Blard.

* A repetition of Forbes's experiments by Mitchell, under the direction of Tait, shows the conductivity to increase with rise of temperature. (Trans. R. S. E. vol. 33, 1887.)

† Jaeger and Diesselhorst. ‡ Herschel, Lebour, and Dunn (British Association Committee).

CONDUCTIVITY FOR HEAT.

TABLE 197. — Various Substances.

Substance.	t °	k_t	Authority.
Asbestos paper	–	.00043	5
Blotting paper	–	.00015	5
Carbon	0	.000405	1
Portland cement	–	.00071	5
Cork	0	.000717	1
Cotton wool	0	.000043	1
Cotton pressed	–	.000033	1
Chalk	–	.002000	2
Ebonite	49	.000370	2
Felt	0	.000087	1
Flannel (dry)	0	.00012	1
Glass { from	–	.0011	3
Glass { to	–	.0023	3
Horn	–	.000087	1
Haircloth	–	.000042	1
Ice {	–	.00223	1
Ice {	–	.00568	4
Leather, cow-hide	–	.00042	5
" chamois	–	.00015	5
Linen	–	.00021	5
Silk	–	.000095	5
Caen stone (building limestone)	–	.00433	2
Calc's sandstone (freestone)	–	.00211	2

1 G. Forbes.
2 H., L., & D.*
3 Various.
4 Neumann.
5 Lees-Chorlton.

TABLE 198. — Water and Salt Solutions.

Substance.	Density.	t °	k_t	Authority.
Water	–	–	.002	1
"	–	0	.00120	2
"	–	9–15	.00136	2
"	–	4	.00129	3
"	–	30	.00157	4
"	–	18	.00124	5
Solutions in water.				
$CuSO_4$	1.160	4.4	.00118	2
KCl	1.026	13	.00116	4
NaCl	33⅓%	10–18	.00267	6
H_2SO_4	1.054	20.5	.00126	5
"	1.100	20.5	.00128	5
"	1.180	21	.00130	5
$ZnSO_4$	1.134	4.5	.00118	2
"	1.136	4.5	.00115	2

1 Bottomley.
2 H. F. Weber.
3 Wachsmuth.
4 Graetz.
5 Chree.
6 Winkelmann.

TABLE 199. — Organic Liquids.

Substance.	t °	k_t ×1000	a	Authority.
Acetic acid	9–15	.472	–	1
Alcohols: amyl	9–15	.328	–	1
ethyl	9–15	.423	–	1
methyl	9–15	.495	–	1
Benzole	5	.333	–	1
Carbon disulphide	9–15	.343	–	1
Chloroform	9–15	.288	–	1
Ether	9–15	.303	–	1
Glycerine	9–15	.637	0.12	2
Oils: olive	–	.395	–	3
castor	–	.425	–	3
petroleum	13	.355	0.011	2
turpentine	13	.325	0.0067	2
Vaseline	–	.44	–	4

1 H. F. Weber.
2 Graetz.
3 Wachsmuth.
4 Lees.

TABLE 200. — Gases.

Substance.	t °	k_t ×10000	a	Authority.
Air	0	.568	.00190	1
Argon	0	.389	.00260	1 2
Ammonia	0	.458	.00548	1
Carbon monoxide	0	.499	–	1
" dioxide	0	.307	–	1
Ethylene	0	.395	.00445	1
Helium	0	3.39	.00318	1 2
Hydrogen	0	3.27	.00175	1
Methane	7–8	.647	–	1
Nitrogen	7–8	.524	–	1
Nitrous oxide	7–8	.350	.00446	1
Oxygen	7–8	.563	–	1

1 Winkelmann.
2 Schwarze.

* Herschel, Lebour, and Dunn (British Association Committee).

HEAT OF COMBUSTION.

Heat of combustion of some common organic compounds.
Products of combustion, CO_2 or SO_2 and water, which is assumed to be in a state of vapor.

Substance.	Small calories per gramme of substance.	Authority.
Acetylene	11923	Thomsen.
Alcohols: Amyl . . .	8958	Favre and Silbermann.
Ethyl . . .	7183	" " "
Methyl . . .	5307	" " "
Benzene	9977	Stohmann, Kleber, and Langbein.
Coals: Bituminous . . .	7400–8500	Various.
Anthracite . . .	7800	Average of various.
Lignite	6900	" " "
Coke	7000	" " "
Carbon disulphide . . .	3244	Berthelot.
Dynamite, 75%	1290	Roux and Sarran.
Gas: Coal gas	5800–11000	Mahler.
Illuminating . . .	5200–5500	Various.
Methane	13063	Favre and Silbermann.
Naphthalene . . .	9618–9793	Various.
Gunpowder	720–750	"
Oils: Lard	9200–9400	"
Olive	9328–9442	Stohmann.
Petroleum, Am. crude .	11094	Mahler.
" " refined .	11045	"
" Russian . .	10800	"
Woods: Beech with 12.9% H_2O	4168	Gottlieb.
Birch " 11.83 "	4207	"
Oak " 13.3 "	3990	"
Pine " 12.17 "	4422	"

HEAT VALUES AND ANALYSES OF VARIOUS TYPES OF FUEL.

(a) Coals.

Coal.	Moisture.	Volatile Matter.	Fixed Carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories per gramme.	B. T. U.'s per pound.
Lignite { Low grade	38.81	25.48	27.29	8.42	.97	7.09	37.45	.50	45.57	3526	6347
Lignite { High grade	33.38	27.44	29.62	9.56	.94	6.77	41.31	.67	40.75	3994	7189
Sub-bituminous { Low grade	22.71	34.78	36.60	5.91	.29	6.14	52.54	1.03	34.09	5115	9207
Sub-bituminous { High grade	15.54	33.03	46.06	5.37	.58	5.89	60.08	1.05	27.03	5865	10557
Bituminous { Low grade	11.44	33.93	43.92	10.71	4.94	5.39	60.06	1.02	17.88	6088	10958
Bituminous { High grade	3.42	34.36	58.83	3.39	.58	5.25	77.98	1.29	11.51	7852	14134
Semi-bituminous { Low grade	2.7	14.5	75.5	7.3	.99	4.58	80.65	1.82	4.66	7845	14121
Semi-bituminous { High grade	3.26	14.57	78.20	3.97	.54	4.76	84.62	1.02	5.09	8166	14699
Semi-anthracite	2.07	9.81	78.82	9.30	1.74	3.62	80.28	1.47	3.59	7612	13702
Anthracite { Low grade	2.76	2.48	82.07	12.69	.54	2.23	79.22	.68	4.64	6987	12577
Anthracite { High grade	3.33	3.27	84.28	9.12	.60	3.08	81.35	.79	5.06	7417	13351

(b) Peats (air dried).

From	Vol. Hydro-Carbon	Fixed Carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories per gramme.	B. T. U.'s per pound.
Franklin Co., N. Y.	67.10	28.99	3.91	.15	5.93	57.17	1.48	31.36	5726	10307
Sawyer Co., Wis.	56.54	27.92	15.54	.29	4.71	51.00	1.92	26.54	4867	8761

(c) Liquid Fuels.

Fuel.	Specific Gravity at 15° C	Calories per gramme.	British Thermal Units per pound.
Petroleum ether	.684–.694	12210–12220	21978–21996
Gasoline	.710–.730	11100–11400	19980–20520
Kerosene	.790–.800	11000–11200	19800–20160
Fuel oils, heavy petroleum or refinery residue	.960–.970	10200–10500	18360–18900
Alcohol, fuel or denatured with 7–9 per cent water and denaturing material	.8196–.8202	6440–6470	11592–11646

Table compiled by U. S. Geological Survey.

CHEMICAL AND PHYSICAL PROPERTIES OF FIVE DIFFERENT CLASSES OF EXPLOSIVES.

Explosive.	Specific gravity.	Number of large calories developed by 1 kilogramme of the explosive.	Pressure developed in own volume after elimination of surface influence.	Unit disruptive charge by ballistic pendulum.	Rate of detonation. Cartridges 1¼ in. diam.	Duration of flame from 100 grammes of explosive.	Length of flame from 100 grammes.	Cartridge 1¼ in. transmitted explosion at a distance of	Products of combustion from 200 grammes; gaseous, solid, and liquid, respectively.	Ignition occurred in 4% fire damp & coal dust mixture with
			Kg. per sq. cm.	Grammes.	Metres per second.	Milliseconds.	Inches.	Inches.	Grammes.	Grammes.
(A) Forty-per-cent nitroglycerin dynamite	1.22	1221.4	8235	227*	4688	.358	24.63	12	88.4 79.7 14.5	25
(B) FFF black blasting powder	1.25	789.4	4817	374† 458*	469.4‡	.925	54.32	–	154.4 126.9 4.1‖	25
(C) Permissible explosive; nitroglycerin class	1.10	760.5	5912	301*	3008	.471	27.79	4	103.9 65.1 15.4	1000
(D) Permissible explosive; ammonium nitrate class	0.97	992.8	7300	279*	3438§	.483	25.68	1	89.8 27.5 75.5	800
(E) Permissible explosive; hydrated class	1.54	610.6	6597	434*	2479	.338	17.49	3	86.1 56.0 33.0	Over 1000

Chemical Analyses.

(A) Moisture	0.91
Nitroglycerin	39.68
Sodium nitrate	42.46
Wood pulp	13.58
Calcium carbonate	3.37
(B) Moisture	0.80
Sodium nitrate	70.57
Charcoal	17.74
Sulphur	10.89
(C) Moisture	7.89
Nitroglycerin	24.02
Sodium nitrate	36.25
Wood pulp and crude fibre from grains	9.20
Starch	21.31
Calcium carbonate	0.97
Magnesium "	0.36
(D) Moisture	0.23
Ammonium nitrate	83.10
Sulphur	0.46
Starch	2.61
Wood pulp	1.89
Poisonous matter	2.54
Manganese peroxide	2.64
Sand	6.53
(E) Moisture	2.34
Nitroglycerin	30.85
Ammonium nitrate	9.94
Sand	1.75
Coal	11.98
Clay	7.64
Ammonium sulphate	8.96
Zinc sulphate (7HO)	6.89
Potassium sulphate	19.65

* One pound of clay tamping used. † Two pounds of clay tamping used. ‡ Rate of burning.
§ Cartridges 1¼ in. diam. ‖ For 300 grammes.

Compiled from U. S. Geological Survey Results, — "Investigation of Explosives for use in Coal Mines, 1909."

Heat of combination of elements and compounds expressed in units, such that when unit mass of the substance is
units, which will be raised in temperature

Substance.	Combined with oxygen forms—	Heat units.	Combined with chlorine forms—	Heat units.	Combined with sulphur forms—	Heat units.	Authority.
Calcium	CaO	3284	$CaCl_2$	4255	CaS	2300	1
Carbon — Diamond	CO_2	7859	–	–	–	–	2
" "	CO	2141	–	–	–	–	3
" — Graphite	CO_2	7796	–	–	–	–	3
Chlorine	Cl_2O	— 254	–	–	–	–	1
Copper	Cu_2O	321	$CuCl$	520	–	–	1
"	CuO	585	$CuCl_2$	819	CuS	158	1
"	"	593	–	–	–	–	4
Hydrogen*	H_2O	34154	HCl	22000	H_2S	2250	3
"	"	34800	–	–	–	–	5
"	"	34417	–	–	–	–	6
Iron	FeO	1353	$FeCl_2$	1464	$FeSH_2O$	428	3
"	–	–	$FeCl_3$	1714	–	–	3
Iodine	I_2O_5	177	–	–	–	–	1
Lead	PbO	243	$PbCl_2$	400	PbS	98	1
Magnesium	MgO	6077	$MgCl_2$	6291	MgS	3191	1
Manganese	$MnOH_2O$	1721	$MnCl_2$	2042	$MnSH_2O_2$	841	1
Mercury	Hg_2O	105	$HgCl$	206	–	–	1
"	HgO	153	$HgCl_2$	310	HgS	84	1
Nitrogen*	N_2O	— 654	–	–	–	–	1
"	NO	— 1541	–	–	–	–	1
"	NO_2	— 143	–	–	–	–	1
Phosphorus (red)	P_2O_5	5272	–	–	–	–	1
" (yellow)	"	5747	–	–	–	–	7
" "	"	5964	–	–	–	–	1
Potassium	K_2O	1745	KCl	2705	K_2S	1312	8
Silver	Ag_2O	27	$AgCl$	271	Ag_2S	24	1
Sodium	Na_2O	3293	$NaCl$	4243	Na_2S	1900	8
Sulphur	SO_2	2241	–	–	–	–	1
"	"	2165	–	–	–	–	2
Tin	SnO	573	$SnCl_2$	690	–	–	4
"	–	–	$SnCl_4$	1089	–	–	7
Zinc	ZnO	1185	–	–	–	–	4
"	"	1314	$ZnCl_2$	1495	–	–	1

Substance.	Combined with $S+O_4$ to form—	Heat units.	Combined with $N+O_3$ to form—	Heat units.	Combined with $C+O_3$ to form—	Heat units.	Authority.
Calcium	$CaSO_4$	7997	$Ca(NO_3)_2$	5080	$CaCO_3$	6730	1
Copper	$CuSO_4$	2887	$Cu(NO_3)_2$	1304	–	–	1
Hydrogen	H_2SO_4	96450	HNO_3	41500	–	–	1
Iron	$FeSO_4$	4208	$Fe(NO_3)_2$	2134	–	–	1
Lead	$PbSO_4$	1047	$Pb(NO_3)_2$	512	$PbCO_3$	814	1
Magnesium	$MgSO_4$	12596	–	–	–	–	1
Mercury	–	–	–	–	–	–	1
Potassium	K_2SO_4	4416	KNO_3	3061	K_2CO_3	3583	1
Silver	Ag_2SO_4	776	$AgNO_3$	266	Ag_2CO_3	561	1
Sodium	Na_2SO_4	7119	$NaNO_3$	4834	Na_2CO_3	5841	1
Zinc	$ZnSO_4$	3538	–	–	–	–	1

AUTHORITIES.

1 Thomsen. 2 Berthelot. 3 Favre and Silbermann. 4 Joule. 5 Hess. 6 Average of seven different. 7 Andrews. 8 Woods.

* Combustion at constant pressure.

IBINATION.

to combine with oxygen or the negative radical, the numbers indicate the amount of water, in the same ° to 1° C. by the addition of that heat.

Substance.	In dilute solutions. Forms —	Heat units.	Forms —	Heat units.	Forms —	Heat units.	Authority.
cium	$CaOH_2O$	3734	$CaCl_2H_2O$	4690	$CaS + H_2O$	2457	1
bon — Diamond	–	–	–	–	–	–	2
" "	–	–	–	–	–	–	3
" — Graphite	–	–	–	–	–	–	3
orine	–	–	–	–	–	–	1
per	–	–	–	–	–	–	1
"	–	–	–	–	–	–	1
"	–	–	–	–	–	–	4
drogen	–	–	–	–	–	–	3
"	–	–	–	–	–	–	5
"	–	–	–	–	–	–	6
	$FeO + H_2O$	1220*	$FeCl_2 + H_2O$	1785	–	–	3
	–	–	$FeCl_3$	2280	–	–	3
ne	–	–	–	–	–	–	1
d	–	–	$PbCl_2$	368	–	–	1
gnesium	MgO_2H_2	9050†	$MgCl_2$	7779	MgS	4784	1
nganese	–	–	$MnCl_2$	2327	–	–	1
cury	–	–	–	–	–	–	1
"	–	–	$HgCl_2$	299	–	–	1
ogen	–	–	–	–	–	–	1
"	–	–	–	–	–	–	1
"	–	–	–	–	–	–	1
sphorus (red)	–	–	–	–	–	–	1
" (yellow)	–	–	–	–	–	–	7
" "	–	–	–	–	–	–	1
ssium	K_2O	2110*	KCl	2592	K_2S	1451	8
er	–	–	–	–	–	–	1
ium	Na_2O	3375	NaCl	4190	Na_2S	2260	8
phur	–	–	–	–	–	–	1
	–	–	–	–	–	–	2
	–	–	$SnCl_2$	691	–	–	7
	–	–	$SnCl_4$	1344	–	–	7
	–	–	–	–	–	–	4
	–	–	$ZnCl_2$	1735	–	–	1

Substance.	In dilute solutions. Forms —	Heat units.	Forms —	Heat units.	Forms —	Heat units.	Authority.
cium	–	–	$Ca(NO_3)_2$	5175	–	–	1
per	$CuSO_4$	3150	$Cu(NO_3)_2$	1310	–	–	1
drogen	H_2SO_4	105300	HNO_3	24550	–	–	1
n	$FeSO_4$	4210	$Fe(NO_3)_3$	2134	–	–	1
d	–	–	$Pb(NO_3)_2$	475	–	–	1
gnesium	$MgSO_4$	13420	$Mg(NO_3)_2$	8595	–	–	1
rcury	–	–	$Hg(NO_3)_2$	335	–	–	1
assium	K_2SO_4	4324	KNO_3	2860	–	–	1
ver	Ag_2SO_4	753	$AgNO_3$	216	–	–	1
lium	Na_2SO_4	7160	$NaNO_3$	4620	Na_2CO_3	5995	1
c	$ZnSO_4$	3820	$Zn(NO_3)_2$	2035	–	–	1

AUTHORITIES.

1 Thomsen. 3 Favre and Silbermann. 5 Hess. 7 Andrews.
2 Berthelot. 4 Joule. 6 Average of seven different. 8 Woods.

* Thomsen. † Total heat from elements.

LATENT HEAT OF VAPORIZATION.

The temperature of vaporization in degrees Centigrade is indicated by T; the latent heat in large calories gramme or in small calories or therms per gramme by H; the total heat from 0° C. in the same units by H' pressure is that due to the vapor at the temperature T.

Substance.	Formula.	T	H	H'	Authority.
Acetic acid	$C_2H_4O_2$	118°	84.9	–	Ogier.
Air	–	–	50.97	–	Fenner-Richtmyer
Alcohol: Amyl	$C_5H_{12}O$	131	120	–	Schall.
Ethyl	C_2H_6O	78.1	205	255	Wirtz.
"	"	0	236	236	Regnault.
"	"	50	–	264	"
"	"	100	–	267	"
"	"	150	–	285	"
Methyl	CH_4O	64.5	2.67	307	Wirtz.
"	"	0	289	289	Ramsay and Your
"	"	50	–	274	" " "
"	"	100	–	246	" " "
"	"	150	–	206	" " "
"	"	200	–	152	" " "
"	"	238.5	–	44.2	" " "
Ammonia	NH_3	7.8	294.2	–	Regnault.
"	"	11	291.3	–	"
"	"	16	297.4	–	"
"	"	17	296.5	–	"
Benzene	C_6H_6	80.1	92.9	127.9	Wirtz.
Bromine	Br	61	45.6	–	Andrews.
Carbon dioxide, solid	CO_2	–	–	138.7	Favre.
" " liquid	"	—25	72.23	–	Cailletet and Math
" " "	"	0	57.48	–	" " "
" " "	"	12.35	44.97	–	Mathias.
" " "	"	22.04	31.8	–	"
" " "	"	29.85	14.4	–	"
" " "	"	30.82	3.72	–	"
" disulphide	CS_2	46.1	83.8	94.8	Wirtz.
" "	"	0	90	90	Regnault.
" "	"	100	–	100.5	"
" "	"	140	–	102.4	"
Chloroform	$CHCl_3$	60.9	58.5	72.8	Wirtz.
Ether	$C_4H_{10}O$	34.5	88.4	107	"
"	"	34.9	90.5	–	Andrews.
"	"	0	94	94	Regnault.
"	"	50	–	115.1	"
"	"	120	–	140	"
Iodine	I	–	23.95	–	Favre and Silberm
Mercury	Hg	357	65	–	Mean.
Nitrogen	N	—195.6	47.65	–	Alt.
Oxygen	O	—182.9	50.97	–	"
Sulphur dioxide	SO_2	0	91.2	–	Cailletet and Math
" "	"	30	80.5	–	" " "
" "	"	65	68.4	–	" " "
Turpentine	$C_{10}H_{10}$	159.3	74.04	–	Brix.
Water	H_2O	100	535.9	–	Andrews.
"	"	100	–	637	Regnault.

LATENT HEAT OF VAPORIZATION.*

ance, formula, and temperature.	l = total heat from fluid at 0° to vapor at $t°$. r = latent heat at $t°$.	Authority.
Acetone, C_3H_6O, −3° to 147°.	$l = 140.5 + 0.36644\,t - 0.000516\,t^2$ $l = 139.9 + 0.23356\,t + 0.00055358\,t^2$ $r = 139.9 - 0.27287\,t + 0.0001571\,t^2$	Regnault. Winkelmann. "
Benzene, C_6H_6, 7° to 215°.	$l = 109.0 + 0.24429\,t - 0.0001315\,t^2$	Regnault.
arbon dioxide, CO_2, −25° to 31°.	$r^2 = 118.485\,(31 - t) - 0.4707\,(31 - t^2)$	Cailletet and Mathias.
bon disulphide, CS_2, −6° to 143°.	$l = 90.0 + 0.14601\,t - 0.000412\,t^2$ $l = 89.5 + 0.16993\,t - 0.0010161\,t^2 + 0.000003424\,t^3$ $r = 89.5 - 0.06530\,t - 0.0010976\,t^2 + 0.000003424\,t^3$	Regnault. Winkelmann. "
on tetrachloride, CCl_4, 8° to 163°.	$l = 52.0 + 0.14625\,t - 0.000172\,t^2$ $l = 51.9 + 0.17867\,t - 0.0009599\,t^2 + 0.000003733\,t^3$ $r = 51.9 - 0.01931\,t - 0.0010505\,t^2 + 0.000003733\,t^3$	Regnault. Winkelmann. "
Chloroform, $CHCl_3$, −5° to 159°.	$l = 67.0 + 0.1375\,t$ $l = 67.0 + 0.14716\,t - 0.0000937\,t^2$ $r = 67.0 - 0.08519\,t - 0.0001444\,t^2$	Regnault. Winkelmann. "
Nitrous oxide, N_2O, −20° to 36°.	$r^2 = 131.75\,(36.4 - t) - 0.928\,(36.4 - t)^2$	Cailletet and Mathias.
lphur dioxide, SO_2, 0° to 60°.	$r = 91.87 - 0.3842\,t - 0.000340\,t^2$	Mathias.

* Quoted from Landolt and Boernstein's "Phys. Chem. Tab." p. 350.

LATENT HEAT OF FUSION.

This table contains the latent heat of fusion of a number of solid substances in large calories per kilogramme or small calories or therms per gramme. It has been compiled principally from Landolt and Börnstein's tables. *C* indicates the composition, *T* the temperature Centigrade, and *H* the latent heat.

Substance.	*C*	*T*	*H*	Authority.
Alloys: 30.5Pb + 69.5Sn	$PbSn_4$	183	17.	Spring.
36.9Pb + 63.1Sn	$PbSn_3$	179	15.5	"
63.7Pb + 36.3Sn	PbSn	177.5	11.6	"
77.8Pb + 22.2Sn	Pb_2Sn	176.5	9.54	"
Britannia metal, 9Sn + 1Pb	–	236	28.0*	Ledebur.
Rose's alloy, 24Pb + 27.3Sn + 48.7Bi	–	98.8	6.85	Mazzotto.
Wood's alloy { 25.8Pb + 14.7Sn + 52.4Bi + 7Cd }	–	75.5	8.40	"
Aluminum	Al	658.	76.8	Glaser.
Ammonia	NH_3	−75.	108.	Massol.
Benzole	C_6H_6	5.4	30.6	Mean.
Bromine	Br	−7.3	16.2	Regnault.
Bismuth	Bi	268	12.64	Person.
Cadmium	Cd	320.7	13.66	"
Calcium chloride	$CaCl_2 + 6H_2O$	28.5	40.7	"
Copper	Cu	1083	42.	Mean.
Iron, Gray cast	–	–	23.	Gruner.
" White "	–	–	33.	"
" Slag	–	–	50.	"
Iodine	I	–	11.71	Favre and Silbermann.
Ice	H_2O	0	79.24	Regnault.
"	"	0	80.02	Bunsen.
" (from sea-water)	{ H_2O + 3.535 of solids }	−8.7	54.0	Petterson.
Lead	Pb	327	5.86	Rudberg.
Mercury	Hg	−39	2.82	Person.
Naphthalene	$C_{10}H_8$	79.87	35.62	Pickering.
Nickel	Ni	1435	4.64	Pionchon.
Palladium	Pd	1545	36.3	Violle.
Phosphorus	P	44.2	4.97	Petterson.
Platinum	Pt	1755	27.2	Violle.
Potassium	K	62	15.7	Joannis.
Potassium nitrate	KNO_3	333.5	48.9	Person.
Phenol	C_6H_6O	25.37	24.93	Petterson.
Paraffin	–	52.40	35.10	Batelli.
Silver	Ag	961	21.07	Person.
Sodium	Na	97	31.7	Joannis.
" nitrate	$NaNO_3$	305.8	64.87	"
" phosphate	{ Na_2HPO_4 + $12H_2O$ }	36.1	66.8	"
Spermaceti	–	43.9	36.98	Batelli.
Sulphur	S	115	9.37	Person.
Tin	Sn	232	14.0	Mean.
Wax (bees)	–	61.8	42.3	"
Zinc	Zn	419	28.13	"

* Total heat from 0° C.

MELTING-POINTS OF THE CHEMICAL ELEMENTS.

Metals in heavier type are often used as standards.
Melting-points are reduced as far as possible to a common temperature scale which is the one used by the United States Bureau of Standards in certifying pyrometers. This scale is defined in terms of Wien's law with C taken as 14000, and on which the melting-point of platinum is 1755° C (Nernst and Wartenburg, 1751; Waidner and Burgess, 1753; Holborn and Valentiner, 1909; see C. R. 148, p. 1177, 1909). Above 1100° C, the temperatures are expressed to the nearest 5° C. Temperatures above the platinum point may be uncertain by over 50° C.

Element.	Melting-point.	Remarks.	Element.	Melting-point.	Remarks.
Aluminum	658 ± 1	Most samples give 657 or less (Burgess).	Manganese	1225	Adjusted.
			Mercury	−39	
Antimony	630 ± 1	"Kahlbaum" purity.	Molybdenum	> 2000	Probably.
			Neodymium	840	(Muthmann-Weiss.)
Argon	−188	Ramsay-Travers.	Neon	−252	
Arsenic	> Sb, < Ag	Under pressure.	**Nickel**	**1450**	Adjusted (Day-Sosman = 1452).
Barium	850	(Guntz.)	Niobium	1950	v. Bolton.
Beryllium	< Ag.		Nitrogen	−211	(Fischer-Alt.)
Bismuth	270	Adjusted.	Osmium	About 2700	(Waidner-Burgess, unpublished.)
Boron	> 2000 < 2500	Weintraub.	Oxygen	−230?	
Bromine	−7.3		**Palladium**	1545 ± 15	(Waidner-Burgess, Nernst-Wartenburg.)
Cadmium	321	Range: 320.7–321.7			
Cesium	26	Range: 26.37–25.3	Phosphorus	44.2	
			Platinum	1755 ± 20	See Note.
Calcium	805	Adjusted.	Potassium	62.5	
Chlorine	−102	(Olszewski.)	Præsodymium	940	(Muthmann-Weiss.)
Carbon	(> 3500)	Sublimes.	Rhodium	1910	(Mendenhall-Ingersoll.)
Cerium	623	(Muthmann-Weiss.)	Rubidium	38.5	
Chromium	1505	Adjusted.	Ruthenium	1900?	
Cobalt	1490	Day-Sosman.	Samarium	1300–1400	(Muthmann-Weiss.)
			Silicon	1420	Adjusted.
Copper	1083 ± 3	Mean, Holborn-Day, Day-Clement.	**Silver**	961 ± 1	Adjusted.
			Sodium	97	
Didymium			Strontium		Between Ca and Ba?
Fluorine	−223	(Moissan - Dewar.)	Sulphur	113.5–119.5	Various forms. See Landolt-Börnstein.
Gallium	30.1		Tantalum	2800	Adjusted from Waidner-Burgess = 2910.
Germanium	< Ag				
Gold	1063 ± 3	Adjusted.	Tellurium	451	Adjusted.
Hydrogen	−259		Thallium	301	
Indium	155	(Thiel.)	Thorium	> 1700 < Pt	v. Wartenburg.
Iodine	114	Range: 112–115.	**Tin**	231.9 ± .2	
Iridium	> 2250 < 2300	Adjusted.	Titanium	?	Above 2000?
Iron	1520	Adjusted.	Tungsten	2950	Mean, Waidner-Burgess and Wartenburg.
Krypton	−169	(Ramsay.)			
Lanthanum	810	(Muthmann-Weiss.)	Uranium	Near Mo	Moissan.
			Vanadium	1750	Vogel-Tammann.
Lead	327 ± 0.5		Xenon	−140	Ramsay.
Lithium	186	(Kahlbaum.)	Zinc	419 ± 0.5	
Magnesium	651	(Grube) in clay crucibles, 635.	Zirconium	> Si	Troost.

BOILING-POINTS OF THE CHEMICAL ELEMENTS.

Element.	Range.	Boiling-point.	Observer; Remarks.
	°	°	
Aluminum	–	1800.	Greenwood, Ch. News, 100, 1909.
Antimony	–	1440.	" " " " "
Argon	–	—186.1	Ramsay-Travers, Z. Phys. Ch. 38, 1901.
Arsenic	449–450	–	Gray, sublimes, Conechy.
"	–	>360.	Black, sublimes, Engel, C. R. 96, 1883.
"	280–310	–	Yellow, sublimes.
Barium	–	–	Boils in vacuo, Guntz, 1903.
Bismuth	1420–1435	1430.	Barus, 1894; Greenwood, l. c.
Boron	–	–	Volatilizes without melting in electric arc.
Bromine	59–63	61.1	Thorpe, 1880; van der Plaats, 1886.
Cæsium	–	670.	Ruff-Johannsen.
Carbon	–	3600.	Computed, Violle, C. R. 120, 1895.
"	–	–	Volatilizes without melting in electric oven, Mo
Cadmium	760–782	770.	
Chlorine	–	—33.6	Regnault, 1863.
Chromium	–	2200.	Greenwood, Ch. News, 100, 1909.
Copper	2100–2310	2310.	" l. c.
Fluorine	–	—187.	Moisson-Dewar, C. R. 136, 1903.
Helium	–	—267.	Computed, Tracers, Ch. News, 86, 1902.
Hydrogen	—252.5–252.8	—252.6	Mean.
Iodine	–	>200.	
Iron	–	2450.	Greenwood, l. c.
Krypton	–	—151.7	Ramsay, Ch. News, 87, 1903.
Lead	–	1525.	Greenwood, l. c.
Lithium	–	1400.	Ruff-Johannsen, Ch. Ber. 38, 1905.
Magnesium	–	1120.	Greenwood, l. c.
Manganese	–	1900.	" "
Mercury	–	357.	Crafts; Regnault.
Nitrogen	—195.7–194.4	—195.	Mean.
Oxygen	—182.5–182.9	—182.7	"
Ozone	–	—119.	Troost, C. R. 126, 1898.
Phosphorus	287–290	288.	
Potassium	667–757	712.	Perman; Ruff-Johannsen.
Rubidium	–	696.	Ruff-Johannsen.
Selenium	664–694	690.	
Silver	–	1955.	Greenwood, l. c.
Sodium	742–757	750.	Perman; Ruff-Johannsen.
Sulphur	444.7–445	444.7	Mean.
Tellurium	–	1390.	Deville-Troost, C. R. 91, 1880.
Thallium	1600–1800	1700.	
Tin	–	2270.	Greenwood, l. c.
Xenon	–	—109.1	Ramsay, Z. Phys. Ch. 44, 1903.
Zinc	916–942	930.	

MELTING-POINTS OF VARIOUS INORGANIC COMPOUNDS.*

Substance.	Chemical Formula.	Melting-point.			Authority.	Date of Publication.
		Min.	Max.	Particular or Average Value.		
Aluminum chloride	$AlCl_3$	–	–	190.	1	1888
" nitrate	$Al(NO_3)_3 + 9H_2O$	–	–	72.8	2	1859
Ammonia	NH_3	–	–	—75.	3	1875
Ammonium nitrate	$(NH_4NO_3$	145.	166.	156.	–	–
" sulphate	$(NH_4)_2SO_4$	–	–	140.	4	1837
" phosphite	$NH_4H_2PO_3$	–	–	123.	5	1887
Antimonietted hydrogen	SbH_3	–	–	—91.5	6	1886
Antimony trichloride	$SbCl_3$	72.	73.2	72.8	–	–
" pentachloride	$SbCl_5$	–	–	—6.	7	1875
Arsenic trichloride	$AsCl_3$	–	–	—18.	8	1903
Arsenietted hydrogen	AsH_3	–	–	—113.5	6	1884
Barium chlorate	$Ba(ClO_3)_2$	–	–	414.	9	1878
" nitrate	$Ba(NO_3)_2$	–	–	593.	9	1878
" perchlorate	$Ba(ClO_4)_2$	–	–	505.	10	1884
Bismuth trichloride	$BiCl_3$	225.	230.	227.5	11	1876
Boric acid	H_3BO_3	184.	186.	185.	9	1878
" anhydride	B_2O_3	–	–	577.	9	1878
Borax (sodium borate)	$Na_2B_4O_7$	–	878.	561.	9	1878
Cadmium chloride	$CdCl_2$	–	590.	541.	9	1878
" nitrate	$Cd(NO_3)_2 + 4H_2O$	–	–	59.5	2	1859
Calcium chloride	$CaCl_2$	719.	806.	762.	–	–
" "	$CaCl_2 + 6H_2O$	–	–	29.6	–	–
" nitrate	$Ca(NO_3)_2$	499.	–	561.	9	1878
" "	$Ca(NO_3)_2 + 4H_2O$	–	–	44.	2	1859
Carbon tetrachloride	CCl_4	–	–	—24.7	12	1863
" trichloride	C_2Cl_6	182.	187.	184.5	–	–
" monoxide	CO	—199.	—207.	203.	–	–
" dioxide	CO_2	—56.5	—57.5	—57.	3	1845
" disulphide	CS_2	–	–	—112.8	14	1903
Chloric acid	$HClO_4 + H_2O$	–	–	50.	15	1861
Chlorine dioxide	ClO_2	–	–	—76.	3	1845
Chrome alum	$KCr(SO_4)_2 + 12H_2O$	–	–	89.	16	1884
" nitrate	$Cr_2(NO_3)_6 + 18H_2O$	–	–	37.	2	1859
Cobalt sulphate	$CoSO_4$	96.	98.	97.	16	1884
Cupric chloride	$CuCl_2$	–	–	498.	9	1878
Cuprous "	Cu_2Cl_2	–	–	434.	9	1878
" nitrate	$Cu(NO_3)_2 + 3H_2O$	–	–	114.5	2	1859
Hydrobromic acid	HBr	–	–	—86.7	3	1845
Hydrochloric "	HCl	–	–	—111.3	17	1900
Hydrofluoric "	HFl	–	–	—92.3	6	1886
Hydroiodic "	HI	49.5	51.3	51.3	17	1900
Hydrogen peroxide	H_2O_2	–	–	—2.	18	–
" phosphide	PH_3	–	–	—132.5	6	1886
" sulphide	H_2S	–	–	—85.6	3	1845
Iron chloride	$FeCl_3$	301.	307.	303.	–	–
" nitrate	$Fe(NO_3)_3 + 9H_2O$	–	–	47.2	2	1859
" sulphate	$FeSO_4 + 7H_2O$	–	–	64.	16	1884
Lead chloride	$PbCl_2$	447.	580.	506.	–	–
" metaphosphate	$Pb(PO_3)_2$	–	–	800.	9	1878
Magnesium chloride	$MgCl_2$	–	–	708.	9	1878
" nitrate	$Mg(NO_3)_2 + 6H_2O$	–	–	90.	2	1859
" sulphate	$MgSO_4 + 5H_2O$	–	–	54.	16	1884
Manganese chloride	$MnCl_2 + 4H_2O$	–	–	87.5	19	–
" nitrate	$Mn(NO_3)_2 + 6H_2O$	–	–	25.8	2	1859
" sulphate	$MnSO_4 + 5H_2O$	–	–	54.	16	1884
Mercuric chloride	$HgCl_2$	287.	293.	290.	–	–

1 Friedel & Crafts. 2 Ordway. 3 Faraday. 4 Marchand. 5 Amat. 6 Olszewski. 7 Kammerer. 8 Baskerville. 9 Carnelley. 10 Carnelley & O'Shea. 11 Muir. 12 Regnault. 13 Wroblewski & Olszewski. 14 Holborn & Wien. 15 Roscoe. 16 Tilden. 17 Ladenburg. 18 Staedel. 19 Clarke, "Const. of Nat."

*For more extensive tables on this subject, see Carnelley's "Melting and Boiling-point Tables," or Landolt and Börnstein's "Phys. Chem. Tab."

MELTING-POINTS OF VARIOUS INORGANIC COMPOUNDS.

Substance.	Chemical Formula.	Melting-point.			Authority	Date of Publication.
		Min.	Max.	Particular or Probable Value.		
Nickel carbonyl	$NiCO_4$	–	–	—25.	1	1890
" nitrate	$Ni(NO_3)_2 + 6H_2O$	–	–	56.7	2	1859
" sulphate	$NiSO_4 + 7H_2O$	98.	100.	99.	3	1884
Nitric acid	HNO_3	–	–	—47.	4	1878
" anhydride	N_2O_5	–	–	30.	5	1872
" oxide *	NO	150.	–	—167.	6	1885
" peroxide	N_2O_4	—9.	—12.	—10.6	–	–
Nitrous anhydride	N_2O_3	–	–	—82.	7	1889
" oxide	N_2O	–	–	—102.3	8	1893
Phosphoric acid (ortho)	H_3PO_4	38.6	41.7	40.3	–	–
Phosphorous acid	H_3PO_3	70.1	74.	72.	–	–
Phosphorus trichloride	PCl_3	–	–	111.8	10	1883
" oxychloride	$POCl_3$	–	–	—1.5	11	1871
" disulphide	P_2S_6	296.	298.	297.	12	1879
" pentasulphide	P_2S_5	274.	276.	275.	13	1879
" sesquisulphide	P_4S_3	142.	167.	158.	–	–
" trisulphide	P_2S_3	–	–	290.	14	1864
Potassium carbonate	K_2CO_3	834.	897.	840.	–	–
" chlorate	$KClO_3$	334.	372.	360.	–	–
" perchlorate	$KClO_4$	–	–	610.	15	1880
" chloride	KCl	740.	804.	779.	–	–
" nitrate	KNO_3	327.	353.	340	–	–
" acid phosphate	KH_2PO_4	–	–	96.	3	1884
" acid sulphate	$KHSO_4$	–	–	200.	16	1840
Silver chloride	AgCl	450.	460.	455.	–	–
" nitrate	$AgNO_3$	198.	224.	214.	–	–
" nitrogenietted	AgN_3	–	–	250.	17	1890
" perchlorate	$AgClO_4$	–	–	486.	18	1884
" phosphate	Ag_3PO_4	–	–	849.	15	1878
" metaphosphate	$AgPO_3$	–	–	482.	15	1878
" sulphate	Ag_2SO_4	654.	676.	665.	–	–
Sodium chloride	NaCl	772.	820.	795.	–	–
" hydroxide	NaOH	–	–	60.	19	1884
" nitrate	$NaNO_3$	308.	330.	315.	–	–
" chlorate	$NaClO_3$	248.	302.	275.	–	–
" perchlorate	$NaClO_4$	–	–	482.	18	1884
" carbonate	Na_2CO_3	814.	920.	852.	–	–
" "	$Na_2CO_3 + 10H_2O$	–	–	34.	3	1884
" phosphate	$Na_2HPO_4 + 4H_2O$	35.	36.4	35.4	–	–
" metaphosphate	$NaPO_3$	–	–	617.	15	1878
" pyrophosphate	$Na_4P_2O_7$	888.	970.	938.	–	–
" phosphite	$(H_2NaPO_3)_2 + 5H_2O$	–	–	42.	20	1888
" sulphate	Na_2SO_4	861.	865.	863.	15	1878
" "	$Na_2SO_4 + 10H_2O$	–	–	34.	3	1884
" hyposulphite	$Na_2S_2O_3 + 5H_2O$	45.	48.1	47.	–	–
Sulphur dioxide	SO_2	73.	79.	76.	–	–
Sulphuric acid	H_2SO_4	10.1	10.6	10.4	21	1884
" "	$12H_2SO_4 + H_2O$	–	–	—0.5	22	1853
" "	$H_2SO_4 + H_2O$	7.5	8.5	8.	–	–
" " (pyro)	$H_2S_2O_7$	–	–	35.	22	1853
Sulphur trioxide	SO_3	14.8	15.	14.9	5	1876–1886
Tin, stannic chloride	$SnCl_4$	–	–	—33.	23	1889
" stannous "	$SnCl_2$	–	–	250.	24	–
Zinc chloride	$ZnCl_2$	–	–	262.	25	1875
" "	$ZnCl_2 + 3H_2O$	–	–	6.5	26	1904
" nitrate	$Zn(NO_3)_2 + 6H_2O$	–	–	36.4	3	1884
" sulphate	$ZnSO_4 + 7H_2O$	–	–	50.	3	1884

1 Mond, Langer & Quincke. 2 Ordway. 3 Tilden. 4 Berthelot. 5 R. Weber. 6 Olszewski. 7 Birhaus. 8 Ramsay. 9 Wills. 10 Wroblewski & Olszewski. 11 Genther & Michaelis. 12 Ramme. 13 V. & C. Meyer. 14 Lemoine. 15 Carnelley. 16 Mitscherlich. 17 Curtius. 18 Carnelley & O'Shea. 19 Cripps. 20 Amat. 21 Mendelejeff. 22 Marignac. 23 Besson. 24 Clarke, "Const. of Nat." 25 Braun. 26 Mylius.

* Under pressure 138 mm. mercury.

BOILING-POINTS OF INORGANIC COMPOUNDS.*

Substance.	Chemical Formula.	Boiling-point.			Authority.	Date of Publication.
		Min.	Max	Particular or Average Values.		
. . . . .	–	–	–	—192.2	1	1884
. . . . .	–	–	–	—191.4	2	1884
inum chloride ‡ . .	$AlCl_3$	–	–	207.5	3	1888
" nitrate . .	$Al(NO_3)_3+9H_2O$	–	–	134.	4	1859
onia	NH_3	–	–	—38.5	5	1863
ionietted hydrogen .	SbH_3	–	–	—18.	2	1886
iony pentachloride § .	$SbCl_5$	102.	103.	–	6	1889
" trichloride .	$SbCl_3$	216.	223.5	220.	–	–
ith trichloride . .	$BiCl_3$	427.	447.	435.	5, 7	–
ium chloride . .	$CdCl_2$	861.	954.	908.	8	1880
nitrate . .	$Cd(NO_3)_2+4H_2O$	–	–	132.	4	1859
im nitrate . . .	$Ca(NO_3)_2+4H_2O$	–	–	132.	4	1859
n dioxide . . .	CO_2	—78.2	—80.	—79.1	–	1863–1880
disulphide . .	CS_2	46.	47.4	46.1	–	–
monoxide . .	CO	190.	—193.	—191.5	2, 1	1884
mic oxychloride .	CrO_2Cl_2	115.9	118.	117.	–	–
nium nitrate . .	$Cr_2(NO_3)_6+18H_2O$	–	–	125.5	4	1859
er nitrate . . .	$Cu(NO_3)_2+3H_2O$	–	–	170.	4	1859
ous chloride . .	Cu_2Cl_2	954.	1032.	993.	8	1880
obromic acid ‖ . .	HBr	–	–	—68.1	9	1900
ochloric acid ‖ . .	HCl	–	–	—83.1	9	1900
ofluoric acid ‖ . .	HF	–	–	—36.7	9	1900
oiodic acid . .	HI	–	–	127.	10	1870
itrate . . .	$Fe(NO_3)_3+9H_2O$	–	–	125.	4	1859
esium nitrate . .	$Mg(NO_3)_2+6H_2O$	–	–	143.	4	1859
anese chloride . .	$MnCl_2+4H_2O$	–	–	106.	11	–
" nitrate . .	$Mn(NO_3)_2+6H_2O$	–	–	129.5	4	1859
uric chloride . .	$HgCl_2$	302.	307.	304.	–	–
el nitrate . . .	$Ni(NO_3)_2+6H_2O$	–	–	136.7	4	1859
ic acid . . .	HNO_3	–	–	86.	12	1830
anhydride . .	N_2O_5	45.	50.	–	13	1849
oxide . . .	NO	–	–	—153.	2	1885
us anhydride . .	N_2O_3	—10.	3.5	–	–	–
oxide . .	N_2O	—87.9	89.8	88.8	–	–
horus trichloride .	PCl_3	73.8	76.	75.	–	–
" sesquisulphide	P_4S_3	–	–	380.	14	1883
" trisulphide .	P_2S_3	–	–	490.	14	1886
" pentasulphide	P_2S_5	518.	530.	522.	–	–
" trioxide . .	P_2O_3	–	–	173.	15	1890
n chloride . .	$SiCl_4$	56.8	59.	58.	–	–
uric acid . . .	$12H_2SO_4+H_2O$	–	–	338.	16	1853
ur trioxide . .	SO_3	46.	47.	46.3	–	–
dioxide . .	SO_2	—8.	—10.5	—9.6	–	–
chloride . .	S_2Cl_2	138.	144.	139.	–	–
tannous chloride .	$SnCl_2$	606.	628.	617.	–	–
tannic " . .	$SnCl_4$	–	–	113.9	17	1876
hloride . . .	$ZnCl_2$	676.	730.	703.	–	–
itrate . . .	$Zn(NO_3)_2+6H_2O$	–	–	131.	4	1859

roblewski.
szewski.
iedel and Crafts.
rdway.
gnault.
nschütz and Evans.

7 Pictet.
8 Carnelley and Carleton-Williams.
9 Ladenburg and Krügel.
10 Topsöe.
11 Clarke, "Const. of Nature."
12 Mitscherlich.
13 Deville.
14 Isambert.
15 Thorpe and Tutton.
16 Marignac.
17 Thorpe.

r a more complete table, see Landolt-Börnstein-Meyerhoffer's Physikalisch-chemische Tabellen.
ssure 76 cm. ‡ Pressure 2.64 atmos. § Pressure 68 mm. ‖ Pressure 75.5 cm.

TABLE 211.—Melting-point of Mixtures.

Metals.	Melting-points, C°. Percentage of metal in second column. 0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%	Reference.
Pb. Sn.	326	290	270	250	230	215	200	180	190	210	232	1
Bi.	322	290	–	–	179	145	126	168	205	–	268	7
Te.	322	710	790	880	917	760	600	480	410	425	446	8
Ag.	328	460	545	590	620	650	705	775	840	905	959	9
Na.	–	360	420	400	370	330	290	250	200	130	96	13
Cu.	326	930	953	953	953	953	953	975	1010	1045	1081	9
Sb.	326	250	275	330	395	440	490	525	560	600	632	16
Al. Sb.	650	750	840	925	945	950	970	1000	1040	1010	632	17
Cu.	650	630	600	560	540	580	610	755	930	1055	1084	18
Au.	655	675	740	800	855	915	970	1025	1055	675	1062	10
Ag.	650	625	615	600	590	580	575	570	650	750	954	17
Zn.	654	640	620	600	580	560	530	510	475	425	419	11
Fe.	654	635	630	1125	1170	1200	1350	1450	1520	1570	1600	3
Sn.	650	645	635	625	620	605	590	570	560	540	232	17
Sb. Bi.	632	610	590	575	555	540	520	470	405	330	268	16
Ag.	630	595	570	545	520	500	505	545	680	850	959	9
Sn.	622	600	570	525	480	430	395	350	310	255	232	19
Zn.	632	555	510	540	570	565	540	525	510	470	419	17
Ni. Sn.	1455	1380	1290	1200	1235	1290	1305	1230	1060	800	232	17
Na. Bi.	96	425	520	590	645	690	720	730	715	570	268	13
Cd.	96	125	185	245	285	325	330	340	360	390	322	13
Cd. Ag.	322	420	520	610	700	760	805	850	895	940	954	17
Tl.	321	300	285	270	262	258	245	230	210	235	302	14
Zn.	322	280	270	295	313	327	340	355	370	390	419	11
Au. Cu.	1063	940	910	925	943	968	993	1018	1040	1060	1083	4
Ag.	1064	1062	1061	1058	1054	1049	1039	1025	1006	982	963	5
Pt.	1075	1125	1190	1250	1320	1380	1455	1530	1610	1685	1775	20
K. Na.	62	17.5	—10	—3.5	5	11	26	41	58	77	97.5	15
Hg.	–	–	–	–	–	90	110	135	162	265	–	13
Tl.	62.5	133	165	188	205	215	220	240	280	305	301	14
Cu. Ni.	1080	1180	1240	1290	1320	1335	1380	1410	1430	1440	1455	17
Ag.	1082	1035	990	945	910	870	830	788	814	875	960	9
Sn.	1084	1005	890	755	725	680	630	580	530	440	232	12
Zn.	1084	1055	1000	945	890	870	840	785	700	570	419	6
Ag. Zn.	959	850	755	705	690	660	630	610	570	505	419	11
Sn.	959	870	750	630	550	495	450	420	375	300	232	9
Na. Hg.	96.5	90	80	70	60	45	22	55	95	215	–	13

1 Roberts-Austen, Engineering, 63, 223, 1897.
2 " " Rap. Cong. Phys. Paris, 1900.
3 " " Engineering, 59, 744, 1895.
4 " " Proc. Roy. Soc. 67, 105, 1900.
5 " " Chem. News, 87, 2, 1903.
6 " " Engineering, 12/2, 221, 1897.
7 Kapp, Diss., Königsberg, 1901.
8 Fay and Gilson, Trans. Am. Inst. Min. Eng. Nov. 1901.
9 Heycock and Neville, Phil. Trans. 189A, 1897.
10 " " " " " 194A, 201, 1900.
11 Heycock and Neville, J. Chem. Soc. 71, 1897.
12 " " " Phil. Trans. 202A, 1, 1903.
13 Kurnakow, Z. Anorg. Chem. 23, 430, 1900.
14 " " " " 30, 86, 1902.
15 " " " " 30, 109, 1902.
16 Roland-Gosselin, Bul. Soc. d'Encour. (5) 1, 1896.
17 Gautier, " " " (5) 1, "
18 Le Chatelier, " " " (4) 10, 573. 1895.
19 Reinders, Z. Anorg. Chem. 25, 113, 1896.
20 Erhard and Schertel, Jahrb. Berg -u. Hüttenw. Sachsen. 1879, 17.

TABLE 212.—Alloy of Lead, Tin, and Bismuth.

	Per cent.									
Lead	32.0	25.8	25.0	43.0	33.3	10.7	50.0	35.8	20.0	70.9
Tin	15.5	19.8	15.0	14.0	33.3	23.1	33.0	52.1	60.0	9.1
Bismuth	52.5	54.4	60.0	43.0	33.3	66.2	17.0	12.1	20.0	20.0
Solidification at	96°	101°	125°	128°	145°	148°	161°	181°	182°	234°

Charpy, Soc. d'Encours, Paris, 1901.

TABLE 213.—Low Melting-point Alloy.

	Per cent.						
Cadmium	10.8	10.2	14.8	13.1	6.2	7.1	6.7
Tin	14.2	14.3	7.0	13.8	9.4	–	–
Lead	24.9	25.1	26.0	24.3	34.4	39.7	43.4
Bismuth	50.1	50.4	52.2	48.8	50.0	53.2	49.9
Solidification at	65.5°	67.5°	68.5°	68.5°	76.5°	89.5°	95°

Drewitz, Diss. Rostock, 1902.

All compiled from Landolt-Börnstein-Meyerhoffer's Physikalisch-chemische Tabellen.

ENSITIES, MELTING-POINTS, AND BOILING-POINTS OF SOME ORGANIC COMPOUNDS.

N.B. — The data in this table refer only to normal compounds.

Substance.	Formula	Temp. °C.	Density.	Melting-point	Boiling-point.	Authority.
(a) Paraffin Series: C_nH_{2n+2}.						
ane*	CH_4	—164.	0.415	–	—165.	Olszewski, Young.
ne†	C_2H_6	0	.446	—171.4	—93.	Ladenburg, "
ane	C_3H_8	0	.536	–	—45.	Young, Hainlen.
ne	C_4H_{10}	0	.60	–	1.	Butlerow, Young.
ane	C_5H_{12}	0	.647	–	36.3	Thorpe, Young.
ne	C_6H_{14}	17.	.663	–	69.	Schorlemmer.
ane	C_7H_{16}	0	.701	–	98.4	Thorpe, Young.
ne	C_8H_{18}	0	.719	–	125.5	" "
ane	C_9H_{20}	0	.733	—51.	150.	Krafft.
ne	$C_{10}H_{22}$	0	.745	—31.	173.	"
ecane	$C_{11}H_{24}$	0	.756	—26.	195.	"
ecane	$C_{12}H_{26}$	0	.765	—12.	214.	"
ecane	$C_{13}H_{28}$	0	.771	—6.	234.	"
adecane	$C_{14}H_{30}$	4.	.775	5.	252.	"
adecane	$C_{15}H_{32}$	10.	.776	10.	270.	"
adecane	$C_{16}H_{34}$	18.	.775	18.	287.	"
tadecane	$C_{17}H_{36}$	22.	.777	22.	303.	"
decane	$C_{18}H_{38}$	28.	.777	28.	317.	"
adecane	$C_{19}H_{40}$	32.	.777	32.	330.	"
sane	$C_{20}H_{42}$	37.	.778	37.	121.§	"
eicosane	$C_{21}H_{44}$	40.	.778	40.	129.§	"
osane	$C_{22}H_{46}$	44.	.778	44.	136.5§	"
osane	$C_{23}H_{48}$	48.	.779	48.	142.5§	"
acosane	$C_{24}H_{50}$	51.	.779	51.	243.‡	"
tacosane	$C_{27}H_{56}$	60.	.780	60.	172.§	"
triacontane	$C_{31}H_{64}$	68.	.781	68.	199.§	"
etyl	$C_{32}H_{66}$	70.	.781	70.	205.§	"
ta-tria-contane	$C_{35}H_{72}$	75.	.782	75.	331.‡	"
(b) Olefines, or the Ethylene Series: C_nH_{2n}.						
ylene	C_2H_4	–	0.610	—169.	—103.	Wroblewski or Olszewski.
pylene	C_3H_6	–	–	–	—50.2	Ladenburg, Krügel.
ylene	C_4H_8	—13.5	.635	–	1.	Sieben.
ylone	C_5H_{10}	–	–	–	36.	Wagner or Saytzeff.
xylene	C_6H_{12}	0	.76	–	69.	Wreden or Znatowicz.
ptylene	C_7H_{14}	19.5	.703	–	96.–99.	Morgan or Schorlemmer.
ylene	C_8H_{16}	17.	.722	–	122.–123.	Mösslinger.
nylene	C_9H_{18}	20.	.767	–	140.–142.	Beilstein, "Org. Chem."
ylene	$C_{10}H_{20}$	–	–	–	175.	" " "
decylene	$C_{11}H_{22}$	20.	.773	–	196.–197.	" " "
decylene	$C_{12}H_{24}$	—31.	.795	—31.	212.–214.	" " "
decylene	$C_{13}H_{26}$	15.	.774	–	233.	Bernthsen.
radecylene	$C_{14}H_{28}$	—12.	.794	—12.	127.‡	Krafft.
tadecylene	$C_{15}H_{30}$	–	.814	–	247.	Bernthsen.
tadecylene	$C_{16}H_{32}$	4.	.792	4.	155.‡	Krafft, Mendelejeff, etc.
adecylene	$C_{18}H_{36}$	18.	.791	18.	179.‡	Krafft.
osylene	$C_{20}H_{40}$	0	.871	–	390.–400.	Beilstein, "Org. Chem."
otene	$C_{27}H_{54}$	–	–	58.	–	Bernthsen.
ene	$C_{30}H_{60}$	–	–	62.	–	"

* Liquid at —11.° C. and 180 atmospheres' pressure (Cailletet).
† " " + 4.° " " 46 " " "
‡ Boiling-point under 15 mm. pressure.
§ In vacuo.

DENSITIES, MELTING-POINTS, AND BOILING-POINTS OF SOME ORGANIC COMPOUNDS.

Substance.	Chemical formula.	Temp. C°.	Specific gravity.	Melting-point.	Boiling-point.	Authority.
(c) Acetylene Series: C_nH_{2n-2}.						
Acetylene	C_2H_2	–	–	—81.	—85.	Villard.
Allylene	C_3H_4	–	–	–	–	
Ethylacetylene	C_4H_6	–	–	–	+ 18.	Bruylants, Kutscheroff, and others.
Propylacetylene	C_5H_8	–	–	–	48.–50.	Bruylants, Taworski.
Butylacetylene	C_6H_{10}	–	–	–	68.–70.	Taworski.
Oenanthylidene	C_7H_{12}	–	–	–	100.–101.	Beilstein, and others.
Caprylidene	C_8H_{14}	0.	0.771	–	133.–134.	Behal.
Undecylidene	$C_{11}H_{20}$	–	–	–	210.–215.	Bruylants.
Dodecylidene	$C_{12}H_{22}$	—9.	.810	— 9.	105.*	Krafft.
Tetradecylidene	$C_{14}H_{26}$	+ 6.5	.806	+ 6.5	134.*	"
Hexadecylidene	$C_{16}H_{30}$	20.	.804	20.	160.*	"
Octadecylidene	$C_{18}H_{34}$	30.	.802	30.	184.*	"
(d) Monatomic alcohols: $C_nH_{2n+1}OH$.						
Methyl alcohol	CH_3OH	0.	0.812	–	66.	From Zander, "Lieb. Ann." vol. 224, p. 85, and Krafft, "Ber." vol. 16, 1714, " 19, 2221, " 23, 2360, and also Wroblewski and Olszewski, "Monatshefte," vol. 4, p. 338.
Ethyl alcohol	C_2H_5OH	0.	.806	—130.†	78.	
Propyl alcohol	C_3H_7OH	0.	.817	–	97.	
Butyl alcohol	C_4H_9OH	0.	.823	–	117.	
Amyl alcohol	$C_5H_{11}OH$	0.	.829	–	138.	
Hexyl alcohol	$C_6H_{13}OH$	0.	.833	–	157.	
Heptyl alcohol	$C_7H_{15}OH$	0.	.836	–	176.	
Octyl alcohol	$C_8H_{17}OH$	0.	.839	–	195.	
Nonyl alcohol	$C_9H_{19}OH$	0.	.842	— 5.	213.	
Decyl alcohol	$C_{10}H_{21}OH$	+ 7.	.839	+ 7.	231.	
Dodecyl alcohol	$C_{12}H_{25}OH$	24.	.831	24.	143.*	
Tetradecyl alcohol	$C_{14}H_{29}OH$	38.	.824	38.	167.*	
Hexadecyl alcohol	$C_{16}H_{33}OH$	50.	.818	50.	190.*	
Octadecyl alcohol	$C_{18}H_{37}OH$	59.	.813	59.	211.*	
(e) Alcoholic ethers: $C_nH_{2n+2}O$.						
Dimethyl ether	C_2H_6O	–	–	–	— 23.6	Erlenmeyer, Kreichbaumer.
Diethyl ether	$C_4H_{10}O$	4.	0.731	— 117	+ 34.6	Regnault, Olszewski.
Dipropyl ether	$C_6H_{14}O$	0.	.763	–	90.7	Zander and others.
Di-iso-propyl ether	$C_6H_{14}O$	0.	.743	–	69.	"
Di-n-butyl ether	$C_8H_{18}O$	0.	.784	–	141.	Lieben, Rossi, and others.
Di-sec-butyl ether	$C_8H_{18}O$	21.	.756	–	121.	Kessel.
Di-iso-butyl "	$C_8H_{18}O$	15.	.762	–	122.	Reboul.
Di-iso-amyl "	$C_{10}H_{22}O$	0.	.799	–	170.–175.	Wurtz.
Di-sec-hexyl "	$C_{12}H_{26}O$	–	–	–	203.–208.	Erlenmeyer and Wanklyn.
Di-norm-octyl "	$C_{16}H_{34}O$	17.	.805	–	280.–282.	Moslinger.
(f) Ethyl ethers: $C_nH_{2n+2}O$.						
Ethyl-methyl ether	C_3H_8O	0.	0.725	–	11.	Wurtz, Williamson.
" propyl "	$C_5H_{12}O$	20.	0.739	–	63.–64.	Chancel, Brühl.
" iso-propyl ether	$C_5H_{12}O$	0.	.745	–	54.	Markownikow.
" norm-butyl ether	$C_6H_{14}O$	0.	.769	–	92.	Lieben, Rossi.
" iso-butyl ether	$C_6H_{14}O$	–	.751	–	78.–80.	Wurtz.
" iso-amyl ether	$C_7H_{16}O$	18.	.764	–	112.	Williamson and others.
" norm-hexyl ether	$C_8H_{18}O$	–	–	–	134.–137.	Lieben, Janeczek.
" norm-heptyl ether	$C_9H_{20}O$	16.	.790	–	165.	Cross.
" norm-octyl ether	$C_{10}H_{22}O$	17.	.794	–	182.–184.	Moslinger.

* Boiling-point under 15 mm. pressure.
† Liquid at —11.° C. and 180 atmospheres' pressure (Cailletet).

LOWERING OF FREEZING-POINTS BY SALTS IN SOLUTION.

In the first column is given the number of gramme-molecules (anhydrous) dissolved in 1000 grammes of water; the second contains the molecular lowering of the freezing-point; the freezing-point is therefore the product of these two columns. After the chemical formula is given the molecular weight, then a reference number.

g. mol. / 1000 g. H_2O	Molecular Lowering.
$Pb(NO_3)_2$, 331.0: 1, 2.	
0.000362	5.5°
.001204	5.30
.002805	5.17
.005570	4.97
.01737	4.69
.5015	2.99
$Ba(NO_3)_2$, 261.5: 1.	
0.000383	5.6°
.001259	5.28
.002681	5.23
.005422	5.13
.008352	5.04
$Cd(NO_3)_2$, 236.5: 3.	
0.00298	5.4°
.00689	5.25
.01997	5.18
.04873	5.15
$AgNO_3$, 167.0: 4, 5.	
0.1566	3.32°
.5001	2.96
.8645	2.87
1.749	2.27
2.953	1.85
3.856	1.64
0.0560	3.82
.1401	3.58
.3490	3.28
KNO_3, 101.9: 6, 7.	
0.0100	3.5
.0200	3.5
.0500	3.41
.100	3.31
.200	3.19
.250	3.08
.500	2.94
.750	2.81
1.000	2.66
$NaNO_3$, 85.09: 2, 6, 7.	
0.0100	3.6°
.0250	3.46
.0500	3.44
.2000	3.345
.500	3.24
.5015	3.30
1.000	3.15
1.0030	3.03
NH_4NO_3, 80.11: 6, 8.	
0.0100	3.6°
.0250	3.50
0.0500	3.47°
.1000	3.42
.2000	3.32
.500	3.26
1.000	3.14
$LiNO_3$, 69.07: 9.	
0.0398	3.4°
.1671	3.35
.4728	3.35
1.0164	3.49
$Al_2(SO_4)_3$, 342.4: 10.	
0.0131	5.6°
.0261	4.9
.0543	4.5
.1086	4.03
.217	3.83
$CdSO_4$, 208.5: 1, 11.	
0.000704	3.35°
.002685	3.05
.01151	2.69
.03120	2.42
.1473	2.13
.4129	1.80
.7501	1.76
1.253	1.86
K_2SO_4, 174.4: 3, 5, 6, 10, 12.	
0.00200	5.4°
.00398	5.3
.00865	4.9
.0200	4.76
.0500	4.60
.1000	4.32
.200	4.07
.454	3.87
$CuSO_4$, 159.7: 1, 4, 11.	
0.000286	3.3°
.000843	3.15
.002279	3.03
.006670	2.79
.01463	2.59
.1051	2.28
.2074	1.95
.4043	1.84
.8898	1.76
$MgSO_4$, 120.4: 1, 4, 11.	
0.000675	3.29
.002381	3.10
.01263	2.72
.0580	2.65
.2104	2.23
0.4978	2.02°
.8112	2.01
1.5233	2.28
$BaCl_2$, 208.3: 3, 6, 13.	
0.00200	5.5°
.00498	5.2
.0100	5.0
.0200	4.95
.04805	4.80
.100	4.69
.200	4.66
.500	4.82
.586	5.03
.750	5.21
$CdCl_2$, 183.3: 3, 14.	
0.00299	5.0°
.00690	4.8
.0200	4.64
.0541	4.11
.0818	3.93
.214	3.39
.429	3.03
.858	2.71
1.072	2.75
$CuCl_2$, 134.5: 9.	
0.0350	4.9°
.1337	4.81
.3380	4.92
.7149	5.32
$CoCl_2$, 129.9: 9.	
0.0276	5.0°
.1094	4.9
.2369	5.03
.4399	5.30
.538	5.5
$CaCl_2$, 111.0: 5, 13–16.	
0.0100	5.1°
.05028	4.85
.1006	4.79
.5077	5.33
.946	5.3
2.432	8.2
3.469	11.5
3.829	14.4
0.0478	5.2
.153	4.91
.331	5.15
.612	5.47
.998	6.34
$MgCl_2$, 95.26: 6, 14.	
0.0100	5.1°
.0500	4.98
.1500	4.96
.3000	5.186
.6099	5.69
KCl, 74.60: 9, 17–19.	
0.02910	3.54°
.05845	3.46
.112	3.43
.3139	3.41
.476	3.37
1.000	3.286
1.989	3.25
3.269	3.25
NaCl, 58.50: 3, 20, 12, 16.	
0.00399	3.7°
.01000	3.67
.0221	3.55
.04949	3.51
.1081	3.48
.2325	3.42
.4293	3.37
.700	3.43
NH_4Cl, 53.52: 6, 15.	
0.0100	3.6°
.0200	3.56
.0350	3.50
.1000	3.43
.2000	3.396
.4000	3.393
.7000	3.41
LiCl, 42.48: 9, 15.	
0.00992	3.7°
.0455	3.5
.09952	3.53
.2474	3.50
.5012	3.61
.7939	3.71
$BaBr_2$, 297.3: 14.	
0.100	5.1°
.150	4.9
.200	5.00
.500	5.18
$AlBr_3$, 267.0: 9.	
0.0078	1.4°
.0559	1.2
.1971	1.07
.4355	1.07

1 Hausrath, Ann. Phys. 9, 1902.
2 Leblanc-Noyes, Z. Phys. Ch. 6, 1890.
3 Jones, Z. Phys. Ch. 11, 1893.
4 Raoult, Z. Phys. Ch. 2, 1888.
5 Arrhenius, Z. Phys. Ch. 2, 1888.
6 Loomis, Wied. Ann. 57, 1896.
7 Jones, Am. Chem. J. 27, 1902.
8 Jones-Caldwell, Am. Chem. J. 5, 1901.
9 Biltz, Z. Phys. Ch. 40, 1902.
10 Jones-Mackay, Am. Chem. J. 19, 1897.
11 Kahlenberg, J. Phys. Ch. 5, 1901.
12 Abegg, Z. Phys. Ch. 20, 1896.
13 Jones-Getman, Am. Ch. J. 27, 1902.
14 Jones-Chambers, Am. Ch. J. 23, 1900.
15 Loomis, Wied. Ann. 60, 1897.
16 Roozeboom, Z. Phys. Ch. 4, 1889.
17 Raoult, Z. Phys. Ch. 27, 1898.
18 Roloff, Z. Phys. Ch. 18, 1895.
19 Kistiakowsky, Z. Phys. Ch. 6, 1890.
20 Loomis, Wied. Ann. 51, 1894.

Compiled from Landolt-Börnstein-Meyerhoffer's Physikalisch-chemische Tabellen.

LOWERING OF FREEZING-POINTS BY SALTS IN SOLUTION (*continued*).

g. mol. / 1000 g. H_2O	Molecular Lowering.
$CdBr_2$, 272.3: 3, 14.	
0.00324	5.1°
.00718	4.6
.03627	3.84
.0719	3.39
.1122	3.18
.220	2.96
.440	2.76
.800	2.59
$CuBr_2$, 223.5: 9.	
0.0242	5.1°
.0817	5.1
.2255	5.27
.6003	5.89
$CaBr_2$, 200.0: 14.	
0.0871	5.1°
.1742	5.18
.3484	5.30
.5226	5.64
$MgBr_2$, 184.28: 14.	
0.0517	5.4°
.103	5.16
.207	5.26
.517	5.85
KBr, 119.1: 9, 21.	
0.0305	3.61°
.1850	3.49
.6801	3.30
.250	3.78
.500	3.30
CdI_2, 366.1: 3, 5, 22.	
0.00210	4.5°
.00626	4.0
.02062	3.52
.04857	2.70
.1360	2.35
.333	2.13
.684	2.23
.888	2.51
KI, 166.0: 9, 2.	
0.0651	3.5°
.2782	3.50
.6030	3.42
1.003	3.37
SrI_2, 341.3: 22.	
0.054	5.1°
.108	5.2
.216	5.35
.327	5.52
NaOH, 40.06: 15.	
0.02002	3.45°
.05005	3.45
.1001	3.41
.2000	3.407
KOH, 56.16: 1, 15, 23.	
0.00352	3.60°
.00770	3.59
.02002	3.44
.05006	3.43
.1001	3.42
.2003	3.424
.230	3.50
.465	3.57
CH_3OH, 32.03: 24, 25.	
0.0100	1.8°
.0301	1.82
.2018	1.811
1.046	1.86
3.41	1.88
6.200	1.944
C_2H_5OH, 46.04: 1, 12, 17, 24-27.	
0.000402	1.67°
.004993	1.67
.0100	1.81
.02892	1.707
.0705	1.85
.1292	1.829
.2024	1.832
.5252	1.834
1.0891	1.826
1.760	1.83
3.901	1.92
7.91	2.02
11.11	2.12
18.76	1.81
0.0173	1.80
.0778	1.79
K_2CO_3, 138.30: 6.	
0.0100	5.1°
.0200	4.93
.0500	4.71
.100	4.54
.200	4.39
Na_2CO_3, 106.10: 6.	
0.0100	5.1°
.0200	4.93
.0500	4.64
.1000	4.42
.2000	4.17
Na_2SO_3, 126.2: 28.	
0.1044	4.51°
.3397	3.74
.7080	3.38
Na_2HPO_4, 142.1: 22, 29.	
0.01001	5.0°
.02003	4.84
.05008	4.60
.1002	4.34
Na_2SiO_3, 122.5: 15.	
0.01052	6.4°
.05239	5.86
.1048	5.28
.2099	4.66
.5233	3.99
HCl, 36.46: 1-3, 6, 13, 18, 22.	
0.00305	3.68°
.00695	3.66
.0100	3.6
.01703	3.59
.0500	3.59
.1025	3.56
.2000	3.57
.3000	3.612
.464	3.68
.516	3.79
1.003	3.95
1.032	4.10
1.500	4.42
2.000	4.97
2.115	4.52
3.000	6.03
3.053	4.90
4.065	5.67
4.657	6.19
HNO_3, 63.05: 3, 13, 15.	
0.02004	3.55°
.05015	3.50
.0510	3.71
.1004	3.48
.1059	3.53
.2015	3.45
.250	3.50
.500	3.62
1.000	3.80
2.000	4.17
3.000	4.64
H_3PO_2, 66.0: 29.	
0.1260	2.90°
.2542	2.75
.5171	2.59
1.071	2.45
HPO, 82.0: 4, 5.	
0.0745	3.0°
.1241	2.8
.2482	2.6
1.00	2.39
H_3PO_4, 98.0: 6, 22.	
0.0100	2.8°
.0200	2.68
.0500	2.49
.1000	2.36
.2000	2.25
0.472	2.20°
.944	2.27
1.620	2.60
$(COOH)_2$, 90.02: 4, 15.	
0.01002	3.3°
.02005	3.19
.05019	3.03
.1006	2.83
.2022	2.64
.366	2.56
.648	2.3
$C_2H_4(OH)_2$, 92.06: 24, 25.	
0.0200	1.86°
.1008	1.86
.2031	1.85
.535	1.91
2.40	1.98
5.24	2.13
$(C_2H_5)_2O$, 74.08: 24.	
0.0100	1.6°
.0201	1.67
.1011	1.72
.2038	1.702
Dextrose, 180.1: 24, 30.	
0.0198	1.84°
.0470	1.85
.1326	1.87
.4076	1.894
1.102	1.921
Levulose, 180.1: 24, 25.	
0.0201	1.87°
.2050	1.871
.554	2.01
1.384	2.32
2.77	3.04
CHO, 342.2: 1, 24, 26.	
0.000332	1.90°
.001410	1.87
.009978	1.86
.0201	1.88
.1305	1.88
H_2SO_4, 98.08: 13, 20, 31-33.	
0.00461	4.8°
.0100	4.49
.0200	4.32
.0461	4.10
.100	3.96
.200	3.85
.400	3.98
1.000	4.19
1.500	4.96
2.000	5.65
2.500	6.53

1-20 *See* page 217.
21 Sherrill, Z. Phys. Ch. 43, 1903.
22 Chambers-Frazer, Am. Ch. J. 23, 1900.
23 Noyes-Whitney, Z. Phys. Ch. 15, 1894.
24 Loomis, Z. Phys. Ch. 32, 1900.
25 Abegg, Z. Phys. Ch. 15, 1894.
26 Nernst-Abegg, Z. Phys. Ch. 15, 1894.
27 Pictet-Altschul, Z. Phys. Ch. 16, 1895.
28 Barth, Z. Phys. Ch. 9, 1892.
29 Petersen, Z. Phys. Ch. 11, 1893.
30 Roth, Z. Phys. Ch. 43, 1903.
31 Wildermann, Z. Phys. Ch. 15, 1894.
32 Jones-Carroll, Am. Ch. J. 28, 1902.
33 Jones-Murray, Am. Ch. J. 30, 1903.

RISE OF BOILING-POINT PRODUCED BY SALTS DISSOLVED IN WATER.*

This table gives the number of grammes of the salt which, when dissolved in 100 grammes of water, will raise the boiling-point by the amount stated in the headings of the different columns. The pressure is supposed to be 76 centimetres.

Salt.	1° C.	2°	3°	4°	5°	7°	10°	15°	20°	25°
$BaCl_2 + 2H_2O$	15.0	31.1	47.3	63.5	(71.6 gives 4°.5 rise of temp.)					
$CaCl_2$	6.0	11.5	16.5	21.0	25.0	32.0	41.5	55.5	69.0	84.5
$Ca(NO_3)_2 + 2H_2O$	12.0	25.5	39.5	53.5	68.5	101.0	152.5	240.0	331.5	443.5
KOH	4.7	9.3	13.6	17.4	20.5	26.4	34.5	47.0	57.5	67.3
$KC_2H_3O_2$	6.0	12.0	18.0	24.5	31.0	44.0	63.5	98.0	134.0	171.5
KCl	9.2	16.7	23.4	29.9	36.2	48.4	(57.4 gives a rise of 8°.5)			
K_2CO_3	11.5	22.5	32.0	40.0	47.5	60.5	78.5	103.5	127.5	152.5
$KClO_3$	13.2	27.8	44.6	62.2						
KI	15.0	30.0	45.0	60.0	74.0	99.5	134.	185.0	(220 gives 18°.5)	
KNO_3	15.2	31.0	47.5	64.5	82.0	120.5	188.5	338.5		
$K_2C_4H_4O_6 + \frac{1}{2}H_2O$	18.0	36.0	54.0	72.0	90.0	126.5	182.0	284.0		
$KNaC_4H_4O_6$	17.3	34.5	51.3	68.1	84.8	119.0	171.0	272.5	390.0	510.0
$KNaC_4H_4O_6 + 4H_2O$	25.0	53.5	84.0	118.0	157.0	266.0	554.0	5510.0		
LiCl	3.5	7.0	10.0	12.5	15.0	20.0	26.0	35.0	42.5	50.0
$LiCl + 2H_2O$	6.5	13.0	19.5	26.0	32.0	44.0	62.0	92.0	123.0	160.5
$MgCl_2 + 6H_2O$	11.0	22.0	33.0	44.0	55.0	77.0	110.0	170.0	241.0	334.5
$MgSO_4 + 7H_2O$	41.5	87.5	138.0	196.0	262.0					
NaOH	4.3	8.0	11.3	14.3	17.0	22.4	30.0	41.0	51.0	60.1
NaCl	6.6	12.4	17.2	21.5	25.5	33.5	(40.7 gives 8°.8 rise)			
$NaNO_3$	9.0	18.5	28.0	38.0	48.0	68.0	99.5	156.0	222.0	
$NaC_2H_3O_2 + 3H_2O$	14.9	30.0	46.1	62.5	79.7	118.1	194.0	480.0	6250.0	
$Na_2S_2O_3$	14.0	27.0	39.0	49.5	59.0	77.0	104.0	152.0	214.5	311.0
Na_2HPO_4	17.2	34.4	51.4	68.4	85.3					
$Na_2C_4H_4O_6 + 2H_2O$	21.4	44.4	68.2	93.9	121.3	183.0	(237.3 gives 8°.4 rise)			
$Na_2S_2O_3 + 5H_2O$	23.8	50.0	78.6	108.1	139.3	216.0	400.0	1765.0		
$Na_2CO_3 + 10H_2O$	34.1	86.7	177.6	369.4	1052.9					
$Na_2B_4O_7 + 10H_2O$	39.	93.2	254.2	898.5	(5555.5 gives 4°.5 rise)					
NH_4Cl	6.5	12.8	19.0	24.7	29.7	39.6	56.2	88.5		
NH_4NO_3	10.0	20.0	30.0	41.0	52.0	74.0	108.0	172.0	248.0	337.0
NH_4SO_4	15.4	30.1	44.2	58.0	71.8	99.1	(115.3 gives 108.2)			
$SrCl_2 + 6H_2O$	20.0	40.0	60.0	81.0	103.0	150.0	234.0	524.0		
$Sr(NO_3)_2$	24.0	45.0	63.6	81.4	97.6					
$C_4H_6O_6$	17.0	34.4	52.0	70.0	87.0	123.0	177.0	272.0	374.0	484.0
$C_2H_2O_4 + 2H_2O$	19.0	40.0	62.0	86.0	112.0	169.0	262.0	540.0	1316.0	50000.0
$C_6H_8O_7 + H_2O$	29.0	58.0	87.0	116.0	145.0	208.0	320.0	553.0	952.0	

Salt.	40°	60°	80°	100°	120°	140°	160°	180°	200°	240°
$CaCl_2$	137.5	222.0	314.0							
KOH	92.5	121.7	152.6	185.0	219.8	263.1	312.5	375.0	444.4	623.0
NaOH	93.5	150.8	230.0	345.0	526.3	800.0	1333.0	2353.0	6452.0	–
NH_4NO_3	682.0	1370.0	2400.0	4099.0	8547.0	∞				
$C_4H_6O_6$	980.0	3774.0	(infinity gives 170)							

* Compiled from a paper by Gerlach, "Zeit. f. Anal. Chem." vol. 26.

FREEZING MIXTURES.*

Column 1 gives the name of the principal refrigerating substance, *A* the proportion of that substance, *B* the proportion of a second substance named in the column, *C* the proportion of a third substance, *D* the temperature of the substances before mixture, *E* the temperature of the mixture, *F* the lowering of temperature, *G* the temperature when all snow is melted, when snow is used, and *H* the amount of heat absorbed in heat units (small calories when *A* is grammes). Temperatures are in Centigrade degrees.

Substance.	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*
$NaC_2H_3O_2$ (cryst.)	85	H_2O–100	–	10.7	—4.7	15.4	–	–
NH_4Cl . . .	30	" "	–	13.3	—5.1	18.4	–	–
$NaNO_3$ . . .	75	" "	–	13.2	—5.3	18.5	–	–
$Na_2S_2O_3$ (cryst.) .	110	" "	–	10.7	—8.0	18.7	–	–
KI	140	" "	–	10.8	—11.7	22.5	–	–
$CaCl_2$ (cryst.) .	250	" "	–	10.8	—12.4	23.2	–	–
NH_4NO_3 . .	60	" "	–	13.6	—13.6	27.2	–	–
$(NH_4)_2SO_4$ . .	25	" 50	NH_4NO_3–25	–	–	26.0	–	–
NH_4Cl . . .	25	" "	" "	–	–	22.0	–	–
$CaCl_2$ . . .	25	" "	" "	–	–	20.0	–	–
KNO_3 . . .	25	" "	NH_4Cl–25	–	–	20.0	–	–
Na_2SO_4 . .	25	" "	" "	–	–	19.0	–	–
$NaNO_3$ . . .	25	" "	" "	–	–	17.0	–	–
K_2SO_4 . . .	10	Snow 100	–	—1	—1.9	0.9	–	
Na_2CO_3 (cryst.) .	20	" "	–	—1	—2.0	1.0	–	–
KNO_3 . . .	13	" "	–	—1	—2.85	1.85	–	–
$CaCl_2$ . . .	30	" "	–	—1	—10.9	9.9	–	–
NH_4Cl . . .	25	" "	–	—1	—15.4	14.4	–	–
NH_4NO_3	45	" "	–	—1	—16.75	15.75	–	–
$NaNO_3$ . . .	50	" "	–	—1	—17.75	16.75	–	–
NaCl . . .	33	" "	–	—1	—21.3	20.3	–	–
$H_2SO_4 + H_2O$ (66.1 % H_2SO_4)	1	" 1.097	–	—1	—37.0	36.0	—37.0	0.0
	1	" 1.26	–	—1	—36.0	35.0	—30.2	17.0
	1	" 1.38	–	—1	—35.0	34.0	—25.0	27.0
	1	" 2.52	–	—1	—30.0	29.0	—12.4	133.0
	1	" 4.32	–	—1	—25.0	24.0	—7.0	273.0
	1	" 7.92	–	—1	—20.0	19.0	—3.1	553.0
	1	" 13.08	–	—1	—16.0	15.0	—2.1	967.0
$CaCl_2 + 6H_2O$	1	" 0.35	–	0	–	–	0.0	52.1
	1	" .49	–	0	–	–	—19.7	49.5
	1	" .61	–	0	–	–	—39.0	40.3
	1	" .70	–	0	–	–	—54.9†	30.0
	1	" .81	–	0	–	–	—40.3	46.8
	1	" 1.23	–	0	–	–	—21.5	88.5
	1	" 2.46	–	0	–	–	—9.0	192.3
	1	" 4.92	–	0	–	–	—4.0	392.3
Alcohol at 4°	77	" 73	–	0	—30.0	–	–	–
	–	CO_2 solid	–	–	—72.0	–	–	–
Chloroform . .	–	" "	–	–	—77.0	–	–	–
Ether . . .	–	" "	–	–	—77.0	–	–	–
Liquid SO_2 . .	–	" "	–	–	—82.0	–	–	–
NH_4NO_3 .	1	H_2O–.75	–	20	5.0	–	–	33.0
	1	" .94	–	20	—4.0	–	–	21.0
	1	" "	–	10	—4.0	–	–	34.0
	1	" "	–	5	—4.0	–	–	40.5
	1	Snow "	–	0	—4.0	–	–	122.2
	1	H_2O–1.20	–	10	—14.0	–	–	17.9
	1	Snow "	–	0	—14.0	–	–	129.5
	1	H_2O–1.31	–	10	—17.5†	–	–	10.6
	1	Snow "	–	0	—17.5†	–	–	131.9
	1	H_2O–3.61	–	10	—8.0	–	–	0.4
	1	Snow "	–	0	—8.0	–	–	327.0

* Compiled from the results of Cailletet and Colardeau, Hammerl, Hanamann, Moritz, Pfanndler, Rudorf, and Tollinger.

† Lowest temperature obtained.

CRITICAL TEMPERATURES, PRESSURES, VOLUMES, AND DENSITIES OF GASES.*

θ = Critical temperature.
P = Pressure in atmospheres.
ϕ = Volume referred to air at 0° and 76 centimetres pressure.
d = Density in grammes per cubic centimetre.

Substance.	θ	P	ϕ	d	Observer.
Air	−140.0	39.0	–	–	Olszewski.
Alcohol (C_2H_6O)	243.6	62.76	0.00713	0.288	Ramsay-Young.
" "	237.9	–	–	–	Mean of ten.
" (CH_4O)	239.95	78.5	–	–	Young.
Ammonia	130.0	115.0	–	–	Dewar.
Argon	−121.0	50.6	–	1.5	Olszewski.
Benzol	288.5	47.9	0.00981	0.305	Young.
Bromine	302.2	–	0.00605	1.18	Nadejdine.
Carbon dioxide	30.92	77	0.0066	–	Andrews.
" monoxide	−141.1	35.9	–	–	Wroblewski.
" disulphide	277.7	78.1	–	–	Hannay.
Chloroform	260.0	54.9	–	–	Sajotschewsky.
Chlorine	141.0	83.9	–	–	Dewar.
"	146.0	–	–	–	Knietsch.
Ether	197.0	35.77	0.01584	0.208	Battelli.
"	194.4	35.61	0.01344	0.262	Young.
Ethane	35.0	45.2	–	–	Dewar.
Ethylene	9.2	58.0	–	–	Van der Waals.
"	13.0	–	0.00569	0.21	Cailletet.
Helium	<−264.0	–	–	–	Dewar.
Hydrogen	−234.5	20.0	–	–	Dewar.
" chloride	51.25	86.0	–	–	Ansdell.
" "	52.3	86.0	–	0.61	Dewar.
" sulphide	100.0	88.7	–	–	Olszewski.
Krypton	−62.5	54.3	–	–	Ramsey-Travers.
Methane	−81.8	54.9	–	–	Olszewski.
"	−99.5	50.0	–	–	Dewar.
Neon	<−205.0	–	–	–	Ramsey-Travers.
Nitric oxide (NO)	−93.5	71.2	–	–	Olszewski.
Nitrogen	−146.0	35.0	–	0.44	"
" monoxide (N_2O)	35.4	75.0	0.0048	0.41	Dewar, Cailletet.
Oxygen	−118.0	50.0	–	0.6044	Wroblewski.
Sulphur dioxide	155.4	78.9	0.00587	0.49	Sajotschewsky, Cailletet.
Water	358.1	–	0.001874	0.429	Nadejdine.
"	364.3	194.6	0.00386	–	Batelli.

Andrews, Trans. Roy. Soc. 166, 1876.
Ansdell, Chem. News, 41, 1880.
Batelli, Mem. Torino (2), 41, 1890.
Cailletet, C. R. 85, 1877; C. R. 94, 1882.
Dewar, Phil. Mag. 18, 1884; Ch. News, 84, 1901.
Hannay, Pr. Roy. Soc. 32, 1882.
Knietsch, Lieb. Ann. 259, 1890.
Nadejdine, Beibl. 9, 1885.
Olszewski, C. R. 98, 1884; 99, 1884; 100, 1885; Beibl. 14, 1890; Z. Phys. Ch. 16, 1893.
Ramsay-Young, Tr. Roy. Soc. 177, 1886.
Sajotschewsky, Beibl. 3, 1879.
Van der Waals, Beibl. 4, 1880.
Wroblewski, Wied. Ann. 20, 1883; Stz. Wien. Ak. 91, 1885.
Young, Phil. Mag. 1900.

* Abridged for the most part from Landolt and Börnstein's "Phys. Chem. Tab."

COEFFICIENTS OF THERMAL EXPANSION.

Coefficients of Linear Expansion of the Chemical Elements.

In the heading of the columns T is the temperature or range of temperature; C is the coefficient of linear expansion; A_1 is the authority for C; M is the mean coefficient of expansion between 0° and 100° C.; α and β are the coefficients in the equation $l_t = l_0 (1 + \alpha t + \beta t^2)$, where l_0 is the length at 0° C. and l_t the length at t° C.; A_2 is the authority for α, β, and m.

Substance.	T	$C \times 10^6$	A_1	$M \times 10^6$	$\alpha \times 10^6$	$\beta \times 10^8$	A_2
Aluminum	40	0.2313	1	0.2220	–	–	2
"	600	.3150	3				
"	−191 to +16	.1835	4	–	.23536	.00707	5
Antimony:							
Parallel to cryst. axis	40	.1692	1				
Perp. to axis	40	.0882	1				
Mean	40	.1152	1	.1056	.0923	.0132	6
Arsenic	40	.0559	1				
Bismuth:							
Parallel to axis	40	.1621	1				
Perp. to axis	40	.1208	1				
Mean	40	.1346	1	.1316	.1167	.0149	6
Cadmium	40	.3069	1	.3159	.2693	.0466	6
Carbon:							
Diamond	40	.0118	1				
Gas carbon	40	.0540	1				
Graphite	40	.0786	1				
Anthracite	40	.2078	1				
Cobalt	40	.1236	1				
Copper	40	.1678	1	.1666	.1481	.0185	6
"	−191 to +16	.1409	4	–	.16070	.00403	5
Gold	40	.1443	1	.1470	.1358	.0112	6
Indium	40	.4170	1				
Iron:							
Soft	40	.1210	1				
Cast	40	.1061	1				
"	−191 to +16	.0850	4				
Wrought	−18 to 100	.1140	7	–	.11705	.005254	8
Steel	40	.1322	1	–	.09173	.008336	8
" annealed	40	.1095	1	.1089	.1038	.0052	9
Lead	40	.2924	1	.2709	.0273	.0074	6
Magnesium	40	.2694	1				
Nickel	40	.1279	1	–	.13460	.003315	8
"	−191 to +16	.1012	4				
Osmium	40	.0657	1				
Palladium	40	.1176	1	–	.11670	.002187	8
Phosphorus	0–40	1.2530	10				
Platinum	40	0.0899	1	–	.08868	.001324	8
Potassium	0–50	.8300	11				
Rhodium	40	.0850	1				
Ruthenium	40	.0960	1				
Selenium	40	.3680	1	.6604	–	–	12
Silicon	40	.0763	1				
Silver	40	.1921	1	–	.18270	.004793	8
"	−191 to +16	.1704	4				
Sulphur:							
Cryst. mean	40	.6413	1	1.180	–	–	12
Tellurium	40	.1675	1	.3687	–	–	12
Thallium	40	.3021	1				
Tin	40	.2234	1	.2296	.2033	.0263	6
Zinc	40	.2918	1	.2976	.2741	.0234	6

1 Fizeau.
2 Calvert, Johnson and Lowe.
3 Chatelier.
4 Henning.
5 Dittenberger.
6 Matthiessen.
7 Andrews.
8 Holborn-Day.
9 Benoit.
10 Pisati and Franchis.
11 Hagen.
12 Spring.

The above table has been partly compiled from the results published by Fizeau, "Comptes Rendus," vol. 68, Matthiessen, "Proc. Roy. Soc.," vol. 15.
The Holborn-Day data are for temperatures from 20° to 1000° C. The Dittenberger, 0° to 600° C.

COEFFICIENTS OF THERMAL EXPANSION.

Coefficients of Linear Expansion for Miscellaneous Substances.

The coefficient of cubical expansion may be taken as three times the linear coefficient. T is the temperature or range of temperature, C the coefficient of expansion, and A the authority.

Substance.	T° C.	$C \times 10^6$	A.
Brass:			
Cast	0–100	0.1875	1
Wire	"	0.1930	1
—	"	.1783–.193	2
71.5Cu+27.7Zn+0.3Sn+0.5Pb	40	0.1859	3
71Cu+29Zn	0–100	0.1906	4
Bronze:			
3Cu+1Sn	16.6–100	0.1844	5
" "	16.6–350	0.2116	5
" "	16.6–957	0.1737	5
86.3Cu+9.7Sn+4Zn	40	0.1782	3
97.6Cu+2.2Sn+0.2P hard	0–80	0.1713	6
97.6Cu+2.2Sn+0.2P soft	"	0.1708	6
Caoutchouc	–	.657–.686	2
"	16.7–25.3	0.770	7
Constantine	4–29	0.4570	–
Ebonite	25.3–35.4	0.842	7
Fluor spar: CaF_2	0–100	0.1950	8
German silver	"	0.1836	8
Gold-platinum: 2Au+1Pt	"	0.1523	4
Gold-copper: 2Au+1Cu	"	0.1552	4
Glass:			
Tube	"	0.0833	1
"	"	0.0828	9
Plate	"	0.0891	10
Crown (mean)	"	0.0897	10
"	50–60	0.0954	11
Flint	"	0.0788	11
Jena thermometer 16^{III} normal	0–100	0.081	12
" 59^{III}	"	0.058	12
" "	–191 to +16	0.424	13
Gutta percha	20	1.983	14
Ice	–20 to –1	0.51	15
Iceland spar:			
Parallel to axis	0–80	0.2631	6
Perpendicular to axis	"	0.0544	6
Lead-tin (solder) 2Pb+1Sn	0–100	0.2508	1
Magnalium	12–39	0.238	16
Marble	15–100	0.117	17
Paraffin	0–16	1.0662	18
"	16–38	1.3030	18
"	38–49	4.7707	18
Platinum-iridium 10Pt+1Ir	40	0.0884	3
Platinum-silver: 1Pt+2Ag	0–100	0.1523	4
Porcelain	20–790	0.0413	19
" Bayeux	1000–1400	0.0553	20
Quartz:			
Parallel to axis	0–80	0.0797	6
" " "	–190 to +16	0.1070	21
Perpend. " "	0–80	0.1337	6
Quartz glass	–190 to +16	–.0026	13
Rock salt	40	0.4040	3
Speculum metal	0–100	0.1933	1
Topaz:			
Parallel to lesser horizontal axis	"	0.0832	8
Parallel to greater horizontal axis	"	0.0836	8
Parallel to vertical axis	"	0.0472	8
Tourmaline:			
Parallel to longitudinal axis	"	0.0937	8
Parallel to horizontal axis	"	0.0773	8
Type metal	16.6–254	0.1952	5
Vulcanite	0–18	0.6360	22
Wedgwood ware	0–100	0.0890	5
Wood:			
Parallel to fibre:			
Ash	"	0.0951	23
Beech	2–34	0.0257	24
Chestnut	"	0.0649	24
Elm	"	0.0565	24
Mahogany	"	0.0361	24
Maple	"	0.0638	24
Oak	"	0.0492	24
Pine	"	0.0541	24
Walnut	"	0.0658	24
Across the fibre:			
Beech	"	0.614	24
Chestnut	"	0.325	24
Elm	"	0.443	24
Mahogany	"	0.404	24
Maple	"	0.484	24
Oak	"	0.544	24
Pine	"	0.341	24
Walnut	"	0.484	24
Wax: White	10–26	2.300	25
"	26–31	3.120	25
"	31–43	4.860	25
"	43–57	15.227	25

1 Smeaton.
2 Various.
3 Fizeau.
4 Matthiessen.
5 Daniell.
6 Benoit.
7 Kohlrausch.
8 Pfaff.
9 Deluc.
10 Lavoisier and Laplace.
11 Pulfrich.
12 Schott.
13 Henning.
14 Russner.
15 Mean.
16 Stadthagen.
17 Fröhlich.
18 Rodwell.
19 Braun.
20 Deville and Troost.
21 Scheel.
22 Mayer.
23 Glatzel.
24 Villari.
25 Kopp.

TABLE 211.—Melting-point of Mixtures.

Metals.	Melting-points, C°. Percentage of metal in second column.											Reference.
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%	
Pb. Sn.	326	290	270	250	230	215	200	180	190	210	232	1
Bi.	322	290	–	–	179	145	126	168	205	–	268	7
Te.	322	710	790	880	917	760	600	480	410	425	446	8
Ag.	328	460	545	590	620	650	705	775	840	905	959	9
Na.	–	360	420	400	370	330	290	250	200	130	96	13
Cu.	326	930	953	953	953	953	953	975	1010	1045	1081	2
Sb.	326	250	275	330	395	440	490	525	560	600	632	16
Al. Sb.	650	750	840	925	945	950	970	1000	1040	1010	632	17
Cu.	650	630	600	560	540	580	610	755	930	1055	1084	18
Au.	655	675	740	800	855	915	970	1025	1055	675	1062	10
Ag.	650	625	615	600	590	580	575	570	650	750	954	17
Zn.	654	640	620	600	580	560	530	510	475	425	419	11
Fe.	654	635	630	1125	1170	1200	1350	1450	1520	1570	1600	3
Sn.	650	645	635	625	620	605	590	570	560	540	232	17
Sb. Bi.	632	610	590	575	555	540	520	470	405	330	268	16
Ag.	630	595	570	545	520	500	505	545	680	850	959	9
Sn.	622	600	570	525	480	430	395	350	310	255	232	19
Zn.	632	555	510	540	570	565	540	525	510	470	419	17
Ni. Sn.	1455	1380	1290	1200	1235	1290	1305	1230	1060	800	232	17
Na. Bi.	96	425	520	590	645	690	720	730	715	570	268	13
Cd.	96	125	185	245	285	325	330	340	360	390	322	13
Cd. Ag.	322	420	520	610	700	760	805	850	895	940	954	17
Tl.	321	300	285	270	262	258	245	230	210	235	302	14
Zn.	322	280	270	295	313	327	340	355	370	390	419	11
Au. Cu.	1063	940	910	925	943	968	993	1018	1040	1060	1083	4
Ag.	1064	1062	1061	1058	1054	1049	1039	1025	1006	982	963	5
Pt.	1075	1125	1190	1250	1320	1380	1455	1530	1610	1685	1775	20
K. Na.	62	17.5	—10	—3.5	5	11	26	41	58	77	97.5	15
Hg.	–	–	–	–	–	90	110	135	162	265	–	13
Tl.	62.5	133	165	188	205	215	220	240	280	305	301	14
Cu. Ni.	1080	1180	1240	1290	1320	1335	1380	1410	1430	1440	1455	17
Ag.	1082	1035	990	945	910	870	830	788	814	875	960	9
Sn.	1084	1005	890	755	725	680	630	580	530	440	232	12
Zn.	1084	1055	1000	945	890	870	840	785	700	570	419	6
Ag. Zn.	959	850	755	705	690	660	630	610	570	505	419	11
Sn.	959	870	750	630	550	495	450	420	375	300	232	9
Na. Hg.	96.5	90	80	70	60	45	22	55	95	215	–	13

1 Roberts-Austen, Engineering, 63, 223, 1897.
2 " " Rap. Cong. Phys. Paris, 1900.
3 " " Engineering, 59, 744, 1895.
4 " " Proc. Roy. Soc. 67, 105, 1900.
5 " " Chem. News, 87, 2, 1903.
6 " " Engineering, 12/2, 221, 1897.
7 Kapp, Diss., Königsberg, 1901.
8 Fay and Gilson, Trans. Am. Inst. Min. Eng. Nov. 1901.
9 Heycock and Neville, Phil. Trans. 189A, 1897.
10 " " " " " 194A, 201, 1900.
11 Heycock and Neville, J. Chem. Soc. 71, 1897.
12 " " " Phil. Trans. 202A, 1, 1903.
13 Kurnakow, Z. Anorg. Chem. 23, 439, 1900.
14 " " " " 30, 86, 1902.
15 " " " " 30, 109, 1902.
16 Roland-Gosselin, Bul. Soc. d'Encour. (5) 1, 1896.
17 Gautier, " " " (5) 1, "
18 Le Chatelier, " " " (4) 10, 573. 1895.
19 Reinders, Z. Anorg. Chem. 25, 113, 1896.
20 Erhard and Schertel, Jahrb. Berg -u. Hütten w. Sachsen. 1879, 17.

TABLE 212.—Alloy of Lead, Tin, and Bismuth.

	Per cent.									
Lead	32.0	25.8	25.0	43.0	33.3	10.7	50.0	35.8	20.0	70.9
Tin	15.5	19.8	15.0	14.0	33.3	23.1	33.0	52.1	60.0	9.1
Bismuth . . .	52.5	54.4	60.0	43.0	33.3	66.2	17.0	12.1	20.0	20.0
Solidification at	96°	101°	125°	128°	145°	148°	161°	181°	182°	234°

Charpy, Soc. d'Encours, Paris, 1901.

TABLE 213.—Low Melting-point Alloy.

	Per cent.						
Cadmium . .	10.8	10.2	14.8	13.1	6.2	7.1	6.7
Tin	14.2	14.3	7.0	13.8	9.4	–	–
Lead	24.9	25.1	26.0	24.3	34.4	39.7	43.4
Bismuth . . .	50.1	50.4	52.2	48.8	50.0	53.2	49.9
Solidification at	65.5°	67.5°	68.5°	68.5°	76.5°	89.5°	95°

Drewitz, Diss. Rostock, 1902.

All compiled from Landolt-Börnstein-Meyerhoffer's Physikalisch-chemische Tabellen.

DENSITIES, MELTING-POINTS, AND BOILING-POINTS OF SOME ORGANIC COMPOUNDS.

N.B. — The data in this table refer only to normal compounds.

Substance.	Formula	Temp. °C.	Density.	Melting-point	Boiling-point.	Authority.
(a) Paraffin Series: C_nH_{2n+2}.						
Methane*	CH_4	—164.	0.415	–	—165.	Olszewski, Young.
Ethane†	C_2H_6	0	.446	—171.4	—93.	Ladenburg, "
Propane	C_3H_8	0	.536	–	—45.	Young, Hainlen.
Butane	C_4H_{10}	0	.60	–	1.	Butlerow, Young.
Pentane	C_5H_{12}	0	.647	–	36.3	Thorpe, Young.
Hexane	C_6H_{14}	17.	.663	–	69.	Schorlemmer.
Heptane	C_7H_{16}	0	.701	–	98.4	Thorpe, Young.
Octane	C_8H_{18}	0	.719	–	125.5	" "
Nonane	C_9H_{20}	0	.733	—51.	150.	Krafft.
Decane	$C_{10}H_{22}$	0	.745	—31.	173.	"
Undecane	$C_{11}H_{24}$	0	.756	—26.	195.	"
Dodecane	$C_{12}H_{26}$	0	.765	—12.	214.	"
Tridecane	$C_{13}H_{28}$	0	.771	—6.	234.	"
Tetradecane	$C_{14}H_{30}$	4.	.775	5.	252.	"
Pentadecane	$C_{15}H_{32}$	10.	.776	10.	270.	"
Hexadecane	$C_{16}H_{34}$	18.	.775	18.	287.	"
Heptadecane	$C_{17}H_{36}$	22.	.777	22.	303.	"
Octadecane	$C_{18}H_{38}$	28.	.777	28.	317.	"
Nonadecane	$C_{19}H_{40}$	32.	.777	32.	330.	"
Eicosane	$C_{20}H_{42}$	37.	.778	37.	121.§	"
Heneicosane	$C_{21}H_{44}$	40.	.778	40.	129.§	"
Docosane	$C_{22}H_{46}$	44.	.778	44.	136.5§	"
Tricosane	$C_{23}H_{48}$	48.	.779	48.	142.5§	"
Tetracosane	$C_{24}H_{50}$	51.	.779	51.	243.‡	"
Heptacosane	$C_{27}H_{56}$	60.	.780	60.	172.§	"
Pentriacontane	$C_{31}H_{64}$	68.	.781	68.	199.§	"
Dicetyl	$C_{32}H_{66}$	70.	.781	70.	205.§	"
Penta-tria-contane	$C_{35}H_{72}$	75.	.782	75.	331.‡	"
(b) Olefines, or the Ethylene Series: C_nH_{2n}.						
Ethylene	C_2H_4	–	0.610	—169.	—103.	Wroblewski or Olszewski.
Propylene	C_3H_6	–	–	–	—50.2	Ladenburg, Krügel.
Butylene	C_4H_8	—13.5	.635	–	1.	Sieben.
Amylene	C_5H_{10}	–	–	–	36.	Wagner or Saytzeff.
Hexylene	C_6H_{12}	0	.76	–	69.	Wreden or Znatowicz.
Heptylene	C_7H_{14}	19.5	.703	–	96.–99.	Morgan or Schorlemmer.
Octylene	C_8H_{16}	17.	.722	–	122.–123.	Möslinger.
Nonylene	C_9H_{18}	20.	.767	–	140.–142.	Beilstein, "Org. Chem."
Decylene	$C_{10}H_{20}$	–	–	–	175.	" " "
Undecylene	$C_{11}H_{22}$	20.	.773	–	196.–197.	" " "
Dodecylene	$C_{12}H_{24}$	—31.	.795	—31.	212.–214.	" " "
Tridecylene	$C_{13}H_{26}$	15.	.774	–	233.	Bernthsen.
Tetradecylene	$C_{14}H_{28}$	—12.	.794	—12.	127.‡	Krafft.
Pentadecylene	$C_{15}H_{30}$	–	.814	–	247.	Bernthsen.
Hexadecylene	$C_{16}H_{32}$	4.	.792	4.	155.‡	Krafft, Mendelejeff, etc.
Octadecylene	$C_{18}H_{36}$	18.	.791	18.	179.‡	Krafft.
Eicosylene	$C_{20}H_{40}$	0	.871	–	390.–400.	Beilstein, "Org. Chem."
Cerotene	$C_{27}H_{54}$	–	–	58.	–	Bernthsen.
Melene	$C_{30}H_{60}$	–	–	62.	–	"

* Liquid at —11.° C. and 180 atmospheres' pressure (Cailletet).
† " " + 4.° " " 46 " " "
‡ Boiling-point under 15 mm. pressure.
§ In vacuo.

COEFFICIENTS OF THERMAL EXPANSION.

Coefficients of Expansion of Gases.

Pressures are given in centimetres of mercury.

Coefficient at Constant Volume.				Coefficient at Constant Pressure.			
Substance.	Pressure cm.	Coefficient × 100.	Reference.	Substance.	Pressure cm.	Coefficient × 100.	Reference.
Air	.6	.37666	1	Air	76.	.3671	3
"	1.3	.37172	"	"	257.	.3693	"
"	10.0	.36630	"	" 0°–100°	100.1	.36728	2
"	25.4	.36580	"	Hydrogen 0°–100°	100.0	.36600	"
"	75.2	.36660	"	"	200 Atm.	.332	9
" 0°–100°	100.1	.36744	2	"	400 "	.295	"
"	76.0	.36650	3	"	600 "	.261	"
"	200.0	.36903	"	"	800 "	.242	"
"	2000.	.38866	"	Carbon dioxide	76.	.3710	3
"	10000.	.4100	"	" " 0°–20°	51.8	.37128	2
Argon	51.7	.3668	4	" " 0°–40°	51.8	.37100	"
Carbon dioxide	76.0	.36856	3	" " 0°–100°	51.8	.37073	"
" "	1.8	.36753	1	" " 0°–20°	99.8	.37602	"
" "	5.6	.36641	"	" " 0°–100°	99.8	.37410	"
" "	74.9	.37264	"	" " 0°–20°	137.7	.37972	"
" " 0°–20°	51.8	.36985	2	" " 0°–100°	137.7	.37703	"
" " 0°–40°	51.8	.36972	"	" " 0°–7.5°	2621.	.1097	6
" " 0°–100°	51.8	.36981	"	" " 64°–100°	2621.	.6574	"
" " 0°–20°	99.8	.37335	"	Carbon monoxide	76.	.3669	3
" " 0°–100°	99.8	.37262	"	Nitrous oxide	76.	.3719	"
" " 0°–100°	100.0	.37248	5	Sulphur dioxide	76.	.3903	"
Carbon monoxide	76.	.36667	3	" "	98.	.3980	"
Helium	56.7	.3665	4	Water-vapor 0°–119°	76.	.4187	10
Hydrogen 16°–132°	.0077	.3328	6	Water-vapor 0°–141°	76.	.4189	"
" 15°–132°	.025	.3623	"	Water-vapor 0°–162°	76.	.4071	"
" 12°–185°	.47	.3656	"	Water-vapor 0°–200°	76.	.3938	"
"	.93	.37002	1	Water-vapor 0°–247°	76.	.3799	"
"	11.2	.36548	"				
"	76.4	.36504	"				
" 0°–100°	100.0	.36626	2				
Nitrogen 13°–132°	.06	.3021	6				
" 9°–133°	.53	.3290	"				
" 0°–20°	100.2	.36754	2				
" 0°–100°	100.2	.36744	"				
"	76.	.36682	7				
Oxygen 11°–132°	.007	.4161	6				
" 9°–132°	.25	.3984	"				
" 11°–132°	.51	.3831	"				
"	1.9	.36683	8				
"	18.5	.36690	"				
"	75.9	.36681	"				
Nitrous oxide	76.	.3676	3				
Sulph'r dioxide SO_2	76.	.3845	"				

Thomson has given, Encyc. Brit. "Heat," the following for the calculation of the expansion, E, between 0° and 100° C. Expansion is to be taken as the change of volume under constant pressure:

Hydrogen, $E = .3662(1 - .00049\,V/v)$,
Air, $E = .3662(1 - .0026\,V/v)$,
Oxygen, $E = .3662(1 - .0032\,V/v)$,
Nitrogen, $E = .3662(1 - .0031\,V/v)$,
CO_2 $E = .3662(1 - .0164\,V/v)$.

V/v is the ratio of the actual density of the gas at 0° C to what it would have at 0° C and 1 Atm. pressure.

1 Meleander, Wied. Beibl. 14, 1890; Wied. Ann. 47, 1892.
2 Chappuis, Trav. Mem. Bur. Intern. Wts. Meas. 13, 1903.
3 Regnault, Ann. chim. phys. (3) 5, 1842.
4 Keunen-Randall, Proc. R. Soc. 59, 1896.
5 Chappuis, Arch. sc. phys. (3), 18, 1892.
6 Baly-Ramsay, Phil. Mag. (5), 38, 1894.
7 Andrews, Proc. Roy. Soc. 24, 1876.
8 Meleander, Acta Soc. Fenn. 19, 1891.
9 Amagat, C. R. 111, 1890.
10 Hirn, Théorie méc. chaleur, 1862.

MECHANICAL EQUIVALENT OF HEAT.

TABLE 224. — Summary.

Taken from J. S. Ames, L'équivalent mécanique de la chaleur, Rapports présentés au congrès international du physique, Paris, 1900.

Name.	Method.	Scale.	Result.	Temp. °C.
Joule	Mechanical		4.173	16.5
Rowland	Mechanical		4.195	10.
			4.187	15.
			4.181	20.
			4.176	25.
Reynolds-Morby	Mechanical		4.1832	Mean-calory.
Griffiths	Electrical	Latimer-Clark = 1.4342v at 15° C.	4.198	15.
			4.192	20.
	$\frac{E^2t}{R}$	International Ohm	4.187	25.
Schuster-Gannon	Electrical Eit.	Latimer-Clark = 1.4340v. at 15° C., Elec. Chem. Equiv. Silver = 0.001118g	4.1905	19.1
Callendar-Barnes	Electrical Eit.	Latimer-Clark = 1.4342v. at 15° C.	4.179	40.

TABLE 225. — Reduced to Gramme-calory at 20° C. (Nitrogen thermometer).

		*
Joule	4.169×10^7 ergs	4.169×10^7 ergs.
Rowland	4.181 " "	4.181 " "
Griffiths	4.192 " "	4.184 " "
Schuster-Gannon	4.189 " "	4.181 " "
Callendar-Barnes	4.186 " "	4.178 " "

* Admitting an error of 1 part per 1000 in the electrical scale.

The mean of the last four then gives

1 small (20° C.) calory = 4.181×10^7 ergs.

TABLE 226. — Conversion Factors for Units of Work.

	Joules Watts per sec. Volt-amp. per sec.	Small 20° Calories.	Ergs.	Kilogramme-metres.	Foot-poundals.	Foot-pounds.
1 joule = 1 watt per second	1	0.2392	10^7	$\frac{1}{g}$	23.73	$\frac{23.73}{g}$
1 small 20° calory =	4.181	1	4.181×10^7	$\frac{4.181}{g}$	99.22	$\frac{99.22}{g}$
1 erg =	10^{-7}	0.2392×10^{-7}	1	$\frac{10^{-7}}{g}$	23.73×10^{-7}	$\frac{23.73}{g} \times 10^{-7}$
1 kilog.-metre =	g	0.2392g	$g \times 10^7$	1	23.73g	23.73
1 foot-poundal =	.04214	.01008	421400.	$\frac{.04214}{g}$	1	$\frac{1}{g}$
1 foot-pound =	.04214g	.01008g	421400g	.04214	g	1

SPECIFIC HEAT OF THE CHEMICAL ELEMENTS.

Element.	Range* of Temperature, °C.	Specific heat.	Reference.
Aluminum	−250	0.1428	1
"	0	.2089	"
"	100	.2226	"
"	250	.2382	"
"	500	.2739	"
"	16–100	.2122	43
Antimony	15	.0489	2
"	100	.0503	"
"	200	.0520	"
Arsenic, gray	0–100	.0822	3
" black	0–100	.0861	"
Barium	−185–+20	.068	4
Bismuth	−186	.0284	5
"	0	.0301	6
"	75	.0309	"
"	20–100	.0302	7
" fluid	280–380	.0363	8
Boron	0–100	.307	9
Bromine, solid	−78–−20	.0843	10
" fluid	13–45	.107	11
Cadmium	21	.0551	2
"	100	.0570	"
"	200	.0594	"
"	300	.0617	"
Cæsium	0–26	.0482	12
Calcium	−185–+20	.157	4
"	0–181	.170	13
Carbon, graphite	−50	.114	14
" "	+11	.160	"
" "	977	.467	"
" diamond	−50	.0635	"
" "	+11	.113	"
" "	985	.459	"
Cerium	0–100	.0448	15
Chlorine, liquid	0–24	.2262	16
Chromium	−200	.0666	17
"	0	.1039	"
"	100	.1121	"
"	600	.1872	"
"	−185–+20	.086	4
Cobalt	500	.1452	18
"	1000	.204	"
"	−182–+15	.0822	19
"	15–100	.1030	"
Copper	17	.0924	2
"	100	.0942	"
"	15–238	.09510	43
"	900	.1259	20
"	−181–+13	.0868	21
"	23–100	.0940	"
Gallium, liquid	to 113	.080	22
" solid	12–23	.079	22
Germanium	0–100	.0737	23
Gold	−185–+20	.033	4
"	0–100	.0316	24
Indium	0–100	.0570	13
Iodine	9–98	0.0541	1
Iridium	−186–+18	.0282	"
"	18–100	.0323	"
Iron, cast †	20–100	.1189	"
" wrought	15–100	.1152	"
" "	1000–1200	.1989	"
" "	500	.176	"
" hard-drawn	0–18	.0986	"
" " "	20–100	.1146	"
"	−185–+20	.0958	"
Lanthanum	0–100	.0448	1
Lead	15	.0299	"
"	100	.0311	"
"	300	.0338	"
" fluid	to 310	.0356	"
" "	" 360	.0410	"
"	18–100	.03096	4
"	16–256	.03191	"
Lithium	−100	.5997	"
"	0	.7951	"
"	50	.9063	"
"	100	1.0407	"
"	190	1.3745	"
Magnesium	−185–+20	0.222	"
"	60	.2492	"
"	325	.3235	"
"	625	.4352	"
"	20–100	.2492	"
Manganese	60	.1211	"
"	325	.1783	"
"	20–100	.1211	"
"	−100	.0979	3
"	0	.1072	"
"	100	.1143	"
Mercury	−185–+20	.032	"
"	0	.03346	3
"	85	.0328	"
"	100	.03284	"
"	250	.03212	"
Molybdenum	−185–+20	.062	"
"	60	.0647	"
"	475	.0750	"
"	20–100	.0647	"
Nickel	−185–+20	.092	"
"	100	.1128	"
"	300	.1403	"
"	500	.1299	"
"	1000	.1608	"
"	18–100	.109	"
Osmium	19–98	.0311	"
Palladium	−186–+18	.0528	"
"	0–100	.0592	"
"	0–1265	.0714	"
Phosphorus, red	0–51	.1829	"
" yellow	13–36	.202	"
" "	−186–+20	.178	"

See opposite page for References.

* Where one temperature alone is given, the "true" specific heat is given; otherwise, the "mean" specific h

† See Appendix. Tables 334-335.

SPECIFIC HEAT.

TABLE 227.—Specific Heat of the Chemical Elements (*continued*).

Element.	Range * of Temperature, °C.	Specific Heat.	Reference.
Platinum	−186–+18	0.0293	26
"	0–100	.0323	24
"	100	.0275	34
"	500	.0356	35
"	700	.0368	"
"	900	.0380	"
"	1100	.0390	"
"	1500	.0407	"
"	500	.0335	"
"	1100	.0358	"
"	1500	.0368	"
Potassium	−185–+20	.170	4
Rhodium	10–97	.0580	25
Ruthenium	0–100	.0611	13
Selenium	−188–+18	.068	36
Silicon	−185–+20	.123	4
"	−39.8	.1360	14
"	+57.1	.1833	"
"	232	.2029	"
Silver	−186–−79	.0496	26
"	−79–+18	.0544	"
"	0–100	.0559	13
"	23	.05498	2
"	100	.05663	"
"	500	.0581	34
"	17–507	.05987	43
"	800	.076	18
" fluid	907–1100	.0748	"
Sodium	−185–+20	.253	4
Sulphur	−188–+18	0.137	36
" rhombic	0–54	.1728	33
" monoclin.	0–52	.1809	"
" liquid	119–147	.235	2
Tantalum	−185–+20	.033	4
Tellurium	−188–+18	.047	36
" crys.	15–100	.0483	37
Thallium	−185–+20	.038	4
"	20–100	.0326	27
Thorium	0–100	.0276	38
Tin	−196–−79	.0486	26
"	−76–+18	.0518	"
" cast	21–109	.0551	30
" fluid	250	.05799	18
" "	1100	.0758	"
Titanium	−185–+20	.082	4
"	0–100	.1125	39
Tungsten	−185–+20	.036	4
"	0–100	.0336	40
Uranium	0–98	.028	41
Vanadium	0–100	.1153	40
Zinc	−192–+20	.0836	27
"	20–100	.0931	"
"	0–100	.0935	13
"	100	.0951	2
"	200	.0996	"
"	300	.1040	"
Zirconium	0–100	.0660	42

1 Boutschew.
2 Naccari, Atti Torine, 23, 1887–88.
3 Wigand, Ann. d. Phys. (4) 22, 1907.
4 Nordmeyer-Bernouli, Verh. d. phys. Ges. 9, 1907; 10, 1908.
5 Giebe, Verh. d. phys. Ges. 5, 1903.
6 Lorenz, Wied. Ann. 13, 1881.
7 Stücker, Wien. Ber. 114, 1905.
8 Person, C. R. 23, 1846; Ann. d. chim. (3) 21, 1847; 24, 1848.
9 Moisson-Gautier, Ann. chim. phys. (7) 17, 1896.
10 Regnault, Ann. d. chim. (3) 26, 1849; 63, 1861.
11 Andrews, Pog. Ann. 75, 1848.
12 Eckardt-Graefe, Z. Anorg. Ch. 23, 1900.
13 Bunsen, Pogg. Ann. 141, 1870; Wied. Ann. 31, 1887.
14 Weber, Phil. Mag. (4) 49, 1875.
15 Hillebrand, Pog. Ann. 158, 1876.
16 Knietsch.
17 Adler, Beibl. 27, 1903.
18 Pionchon, C. R. 102–103, 1886.
19 Tilden, Phil. Trans. (A) 201, 1903.
20 Richards, Ch. News, 68, 1893.
21 Trowbridge, Science, 8, 1898.
22 Berthelot, Ann. d. chim. (5) 15, 1878.
23 Pettersson-Hedellius, J. Pract. Ch. 24, 1881.
24 Violle, C. R. 85, 1877; 87, 1878.
25 Regnault, Ann. d. chim. (2) 73, 1840; (3) 63, 1861.
26 Behn, Wied. Ann. 66, 1898; Ann. d. Phys. (4) 1, 1900.
27 Schmitz, Pr. Roy. Soc. 72, 1903.
28 Nichol, Phil. Mag. (5) 12, 1881.
29 Hill, Verh. d. phys. Ges. 3, 1901.
30 Spring, Bull. de Belg. (3) 11, 1886; 29, 1895.
31 Laemmel, Ann. d. Phys. (4) 16, 1905.
32 Barnes-Cooke, Phys. Rev. 16, 1903.
33 Wiegand, Fort. d. Phys. 1906.
34 Tilden, Pr. Roy. Soc. 66, 1900, 71, 1903; Phil. Trans. (A) 194, 1900; 201, 1903.
35 White, Phys. Rev. 28, 1909.
36 Dewar, Ch. News, 92, 1905.
37 Kopp, Phil. Trans. London, 155, 1865.
38 Nilson, C. R. 96, 1883.
39 Nilson-Pettersson, Zt. phys. Ch. 1, 1887.
40 Mache, Wien. Ber. 106, 1897.
41 Blümcke, Wied. Ann. 24, 1885.
42 Mixter-Dana, Lieb. Ann. 169, 1873.
43 Magnus, Ann. d. Phys. 31, 1910.

* When one temperature alone is given, the "true" specific heat is given; otherwise, the "mean" specific heat.

Compiled in part from Landolt-Börnstein-Meyerhoffer's Physikalisch-chemische Tabellen.

TABLE 228.—Specific Heat of Water and of Mercury.

Specific Heat of Water.							Specific Heat of Mercury.			
Temperature, °C.	Barnes.	Rowland.	Barnes-Regnault.	Temperature, °C.	Barnes.	Barnes-Regnault.	Temperature, °C.	Specific Heat.	Temperature, °C.	Specific Heat.
−5	1.0155	–	–	60	0.9988	0.9994	0	0.03346	90	0.03277
0	1.0091	–	1.0094	65	.9994	1.0004	5	.03340	100	.03269
+5	1.0050	1.0054	1.0053	70	1.0001	1.0015	10	.03335	110	.03262
10	1.0020	1.0019	1.0023	80	1.0014	1.0042	15	.03330	120	.03255
15	1.0000	1.0000	1.0003	90	1.0028	1.0070	20	.03325	130	.03248
20	0.9987	0.9979	0.9990	100	1.0043	1.0101	25	.03320	140	.03241
25	.9978	.9972	.9981	120	–	1.0162	30	.03316	150	.0324
30	.9973	.9969	.9976	140	–	1.0223	35	.03312	170	.0322
35	.9971	.9981	.9974	160	–	1.0285	40	.03308	190	.0320
40	.9971	–	.9974	180	–	1.0348	50	.03300	210	.0319
45	.9973	–	.9976	200	–	1.0410	60	.03294	–	–
50	.9977	–	.9980	220	–	1.0476	70	.03289	–	–
55	.9982	–	.9985	–	–	–	80	.03284	–	–

Barnes's results: Phil. Trans. (A) 199, 1902; Phys. Rev. 15, 1902; 16, 1903. (H thermometer.)
Rowland's as revised by Pernet. (H thermometer.) Barnes-Regnault's as revised by Peabody; Steam Tables.
The mercury data from 0° C to 80, Barnes-Cooke (H thermometer); from 90° to 140, mean of Winklemann, Naccari and Milthaler (air thermometer); above 140°, mean of Naccari and Milthaler.

TABLE 229.—Specific Heat of Various Solids.*

Solid.	Temperature °C.	Specific Heat.	Authority.†
Alloys:			
Bell metal	15–98	0.0858	R
Brass, red	0	.08991	L
" yellow	0	.08831	"
80 Cu+20 Sn	14–98	.0862	R
88.7 Cu+11.3 Al	20–100	.10432	Ln
German silver	0–100	.09464	T
Lipowitz alloy: 24.97 Pb + 10.13 Cd + 50.66 Bi +14.24 Sn	5–50	.0345	M
" "	100–150	.0426	"
Rose's alloy: 27.5 Pb+48.9 Bi+23.6 Sn	−77–20	.0356	S
" "	20–89	.0552	"
Wood's alloy: 25.85 Pb + 6.99 Cd + 52.43 Bi + 14.73 Sn	5–50	.0352	M
" " (fluid)	100–150	.0426	"
Miscellaneous alloys:			
17.5 Sb+29.9 Bi+18.7 Zn+33.9 Sn	20–99	.05657	R
37.1 Sb+62.9 Pb	10–98	.03880	"
39.9 Pb+60.1 Bi	16–99	.03165	P
" " (fluid)	144–358	.03500	"
63.7 Pb+36.3 Sn	12–99	.04073	R
46.7 Pb+53.3 Sn	10–99	.04507	"
63.8 Bi+36.2 Sn	20–99	.04001	"
46.9 Bi+53.1 Sn	20–99	.04504	"
Gas coal	20–1040	.3145	–
Glass, normal thermometer 16^{III}	19–100	.1988	W
" French hard thermometer	–	.1869	Z
" crown	10–50	.161	H M
" flint	10–50	.117	"
Ice	−188–−252	.146	D
"	−78–−188	.285	"
"	−18–−78	.463	"
India rubber (Para)	?–100	.481	G-T
Paraffin	−20–+3	.3768	R W
"	−19–+20	.5251	"
"	0–20	.6939	"
"	35–40	.622	B
" fluid	60–63	.712	"
Vulcanite	20–100	.3312	A M

TABLE 230.—Specific Heat of Various Liquids.*

Liquid.	Temperature °C.	Specific Heat.	Authority.	Liquid.	Temperature °C.	Specific Heat.	Authority.†
Alcohol, ethyl	−20	0.5053	R	Nitrobenzole	28	0.362	A
" "	0	.548	"	Napthalene, $C_{10}H_8$	80–85	.396	B
" "	40	.648	"	"	90–95	.409	"
" methyl	5–10	.590	"	Oils: castor	–	.434	W
" "	15–20	.601	"	citron	5.4	.438	H W
Anilin	15	.514	G	olive	6.6	.471	"
"	30	.520	"	sesame	–	.387	W
"	50	.529	"	turpentine	0	.411	R
Benzole, C_6H_6	10	.340	H-D	Petroleum	21–58	.511	Pa
"	40	.423	"	Toluol, C_6H_8	10	.364	H-D
"	65	.482	"	"	65	.490	"
Diphenylamine, $C_{12}H_{11}N$	53	.464	B	"	85	.534	"
"	65	.482	"	$CaCl_2$, sp. gr. 1.14	−15	.764	DMG
Ethyl ether	0	.529	R	" " "	0	.775	"
Glycerine	15–50	.576	E	" " "	+20	.787	"
Nitrobenzole	14	.350	A	" " 1.20	−20	.695	"

* These specific heat tables are compiled partly from more extended tables in Landolt-Börnstein-Meyerhoffer's Tables.
† For references see Table 230, page 231.

TABLE 230.—Specific Heat of Various Liquids.

Liquid.	Temperature °C.	Specific Heat.	Authority.	Liquid.	Temperature °C.	Specific Heat.	Authority.
Cl_2, sp. gr. 1.20	0	0.712	DMG	KOH + 30 H_2O	18	0.876	TH
" "	+20	.725	"	" + 100 "	18	.975	"
" 1.26	−20	.651	"	NaOH + 50 H_2O	18	.942	"
" "	0	.663	"	" + 100 "	18	.983	"
" "	+20	.676	"	NaCl + 10 H_2O	18	.791	"
SO_4 + 50 H_2O	12–15	.848	Pa	" + 200 "	18	.978	"
+200 "	12–14	.951	"	Sea water, sp. gr. 1.0043	17.5	.980	"
+400 "	13–17	.975	"	" " " 1.0235	17.5	.938	"
SO_4 + 50 H_2O	20–52	.842	Ma	" " " 1.0463	17.5	.903	"
+200 "	20–52	.952	"				

Abbot.
I, A. M. Mayer.
Batelli.
Dewar.
Emo.
Griffiths.
I, Gee and Terry.
DMG, Dickinson, Mueller, and George.
H-D, de Heen and Deruyts.
HM, H. Meyer.
L, Lorenz.
Ln, Luginen.
M, Mazotto.
Ma, Marignac.
P, Person.
Pa, Pagliani.
R, Regnault.
RW, R. W. Weber.
T, Tomlison.
S, Schüz.
Th, Thomsen.
W, Wachsmuth.
Wn, Winkelmann.
Z, Zouloff.

TABLE 231.—Specific Heat of Minerals and Rocks.

Substance.	Temperature °C.	Specific Heat.	Reference.	Substance.	Temperature °C.	Specific Heat.	Reference.
alusite	0–100	0.1684	1	Rock-salt	13–45	0.219	6
ydrite, $CaSO_4$	0–100	.1753	1	Serpentine	16–98	.2586	2
tite	15–99	.1903	2	Siderite	9–98	.1934	4
estos	20–98	.195	3	Spinel	15–47	.194	6
ite	20–98	.1931	3	Talc	20–98	.2092	3
te, $BaSO_4$	10–98	.1128	4	Topaz	0–100	.2097	1
l	15–99	.1979	2	Wollastonite	19–51	.178	6
x, $Na_2B_4O_7$ fused	16–98	.2382	4	Zinc blende, ZnS	0–100	.1146	1
spar, $CaCO_3$	0–50	.1877	1	Zircon	21–51	.132	6
" "	0–100	.2005	1	Rocks:			
" "	0–300	.2204	1	Basalt, fine, black	12–100	.1996	6
derite, SnO_2	16–98	.0933	4	" " "	20–470	.199	9
ndum	9–98	.1976	4	" " "	470–750	.243	9
olite, $Al_2Fl_6.6NaF$	16–99	.2522	2	" " "	750–880	.626	9
rite, CaF_2	15–99	.2154	4	" " "	880–1190	.323	9
na, PbS	0–100	.0466	5	Dolomite	20–98	.222	3
et	16–100	.1758	2	Gneiss	17–99	.196	10
natite, Fe_2O_3	15–99	.1645	2	"	17–213	.214	10
nblende	20–98	.1952	3	Granite	12–100	.192	7
ersthene	20–98	.1914	3	Kaolin	20–98	.224	3
radorite	20–98	.1949	3	Lava, Aetna	23–100	.201	11
netite	18–45	.156	6	" "	31–776	.259	11
achite, $Cu_2CO_4.H_2O$	15–99	.1763	2	" Kilauea	25–100	.197	11
(Mg)	20–98	.2061	3	Limestone	15–100	.216	12
(K)	20–98	.2080	3	Marble	0–100	.21	–
oclase	20–98	.2048	3	Quartz sand	20–98	.191	3
oclase	15–99	.1877	2	Sandstone	–	.22	–
tes, copper	15–99	.1291	2				
lusite, MnO_2	17–48	.159	6				
rtz, SiO_2	12–100	.188	7				
"	0	.1737	8				
"	350	.2786	8				
"	400–1200	.305	8				

1 Lindner.
2 Oeberg.
3 Ulrich.
4 Regnault.
5 Tilden.
6 Kopp.
7 Joly.
8 Pionchon.
9 Roberts-Austen, Rücker.
10 R. Weber.
11 Bartoli.
12 Morano.

Compiled from Landolt-Börnstein-Meyerhoffer's Physikalisch-chemische Tabellen.

TABLE 232.

SPECIFIC HEATS OF GASES AND VAPORS.

Substance.	Range of Temp. °C.	Sp. Ht. Constant Pressure.	Authority.	Range of Temp. °C.	Mean Ratio of Specific Heats. C_p/C_v.	Authority.
Acetone, C_3H_6O	26–110	0.3468	Wiedemann.			
" "	27–179	0.3740	"			
" "	129–233	0.4125	Regnault.			
Air	−30–+10	0.2377	"	5–14	1.4025	Lummer and Pringsheim
"	0–100	0.2374	"			
"	0–200	0.2375	"			
"	20–440	0.2366	Holborn and Austin.			
"	20–630	0.2429				
"	20–800	0.2430	"			
Alcohol, C_2H_5OH	108–220	0.4534	Regnault.	53	1.133	Jaeger.
" "	–	–	–	100	1.134	Stevens.
" C_2H_5OH	101–223	0.4580	Regnault.	100	1.256	"
Ammonia	23–100	0.5202	Wiedemann.	0	1.3172	Wüllner.
"	27–200	0.5356	"	100	1.2770	"
"	24–216	0.5125	Regnault.			
Argon	20–90	0.1233	Dittenberger.	0	1.667	Niemeyer.
Benzole, C_6H_6	34–115	0.2990	Wiedemann.	20	1.403	Pagliani.
" "	35–180	0.3325	"	60	1.403	"
" "	116–218	0.3754	Regnault.	99.7	1.105	Stevens
Bromine	83–228	0.0555	"	20–388	1.293	Strecker.
"	19–388	0.0553	Strecker.			
Carbon dioxide, CO_2	−28–+7	0.1843	Regnault.	4–11	1.2995	Lummer and Pringsheim
" " "	15–100	0.2025	"			
" " "	11–214	0.2169	"			
" monoxide, CO	23–99	0.2425	Wiedemann.	0	1.403	Wüllner.
" " "	26–198	0.2426	"	100	1.395	"
" disulphide, CS_2	86–190	0.1596	Regnault.	3–67	1.205	Beyme.
Chlorine	13–202	0.1241	"	20–340	1.323	Strecker.
"	16–343	0.1125	Strecker.	0	1.336	Martini.
Chloroform, $CHCl_3$	27–118	0.1441	Wiedemann.	22–78	1.102	Beyme.
" "	28–189	0.1489	"	99.8	1.150	Stevens.
Ether, $C_4H_{10}O$	69–224	0.4797	Regnault.	3–46	1.025	Beyme.
" "	27–189	0.4618	Wiedemann.	42–45	1.029	Müller.
" "	25–111	0.4280	"	12–20	1.024	Low.
Hydrochloric acid, HCl	13–100	0.1940	Strecker.	20	1.389	Strecker.
" " "	22–214	0.1867	Regnault.	100	1.400	"
Hydrogen	−28–+9	3.3996	"	4–16	1.4080	Lummer and Pringsheim
"	12–198	3.4090	"			
"	21–100	3.4100	Wiedemann.			
" sulphide, H_2S	20–206	0.2451	Regnault.	10–40	1.276	Müller.
Methane, CH_4	18–208	0.5929	"	11–30	1.316	"
Nitrogen	0–200	0.2438	"	–	1.41	Cazin.
"	20–440	0.2419	Holborn and Austin.			
"	20–630	0.2464				
"	20–800	0.2497	"			
Nitric oxide, NO	13–172	0.2317	Regnault.			
Nitrogen tetroxide, NO_2	27–67	1.625	Berthelot and Olger.	–	1.31	Natanson.
" " "	27–150	1.115				
" " "	27–280	0.65	"			
Nitrous oxide, N_2O	16–207	0.2262	Regnault.	0	1.311	Wüllner.
" " "	26–103	0.2126	Wiedemann.	100	1.272	"
" " "	27–206	0.2241	"			
Oxygen	13–207	0.2175	Regnault.	5–14	1.3977	Lummer and Pringsheim
"	20–440	0.2240	Holborn and Austin.			
"	20–630	0.2300				
Sulphur dioxide, SO_2	16–202	0.1544	Regnault.	16–34	1.256	Müller.
Water vapor, H_2O	0	0.4655	Thiesen.	78	1.274	Beyme.
" " "	100	0.421	"	94	1.33	Jaeger.
" " "	180	0.51	"			

THERMOMETERS.

TABLE 233. — Gas and Mercury Thermometers.

If t_H, t_N, t_{CO_2}, t_{16}, t_{59}, t_T, are temperatures measured with the hydrogen, nitrogen, carbonic acid, 16^{III}, 59^{III}, and "verre dur" (Tonnelot), respectively, then

$$t_H - t_T = \frac{(100 - t)t}{100^2}\,[-0.61859 + 0.0047351.t - 0.000011577.t^2]*$$

$$t_N - t_T = \frac{(100 - t)t}{100^2}\,[-0.55541 + 0.0048240.t - 0.000024807.t^2]*$$

$$t_{CO_2} - t_T = \frac{(100 - t)t}{100^2}\,[-0.33386 + 0.0039910.t - 0.000016678.t^2]*$$

$$t_H - t_{16} = \frac{(100 - t)t}{100^2}\,[-0.67039 + 0.0047351.t - 0.000011577.t^2]\dagger$$

$$t_H - t_{59} = \frac{(100 - t)t}{100^2}\,[-0.31089 + 0.0047351.t - 0.000011577.t^2]\dagger$$

* Chappuis; Trav. et Mém. du Bur. internat. des Poids et Mes. 6, 1888.
† Thiesen, Scheel, Sell; Wiss. Abh. d. Phys. Techn. Reichanstalt, 2, 1895; Scheel; Wied. Ann. 58, 1896; D. Mech. Ztg. 1897.

TABLE 234. $t_H - t_{16}$ (Hydrogen — 16^{III}).

	0°	1°	2°	3°	4°	5°	6°	7°	8°	9°
0°	.000°	—.007°	—.013°	—.019°	—.025°	—.031°	—.036°	—.042°	—.047°	—.051°
10	—.056	—.061	—.065	—.069	—.073	—.077	—.080	—.084	—.087	—.090
20	—.093	—.096	—.098	—.101	—.103	—.105	—.107	—.109	—.110	—.112
30	—.113	—.114	—.115	—.116	—.117	—.118	—.119	—.119	—.119	—.120
40	—.120	—.120	—.120	—.120	—.119	—.119	—.118	—.118	—.117	—.116
50	—.116	—.115	—.114	—.113	—.111	—.110	—.109	—.107	—.106	—.104
60	—.103	—.101	—.099	—.097	—.096	—.094	—.092	—.090	—.087	—.085
70	—.083	—.081	—.078	—.076	—.074	—.071	—.069	—.066	—.064	—.061
80	—.058	—.056	—.053	—.050	—.048	—.045	—.042	—.039	—.036	—.033
90	—.030	—.027	—.024	—.021	—.018	—.015	—.012	—.009	—.006	—.003
100	.000									

TABLE 235. $t_H - t_{59}$ (Hydrogen — 59^{III}).

	0°	1°	2°	3°	4°	5°	6°	7°	8°	9°
0°	.000°	—.003°	—.006°	—.009°	—.011°	—.014°	—.016°	—.018°	—.020°	—.022°
10	—.024	—.025	—.027	—.028	—.030	—.031	—.032	—.033	—.034	—.035
20	—.035	—.036	—.036	—.037	—.037	—.037	—.038	—.038	—.038	—.038
30	—.038	—.037	—.037	—.037	—.037	—.036	—.036	—.035	—.035	—.034
40	—.034	—.033	—.032	—.032	—.031	—.030	—.029	—.028	—.028	—.027
50	—.026	—.025	—.024	—.023	—.022	—.021	—.020	—.019	—.018	—.017
60	—.016	—.015	—.015	—.014	—.013	—.012	—.011	—.010	—.009	—.008
70	—.008	—.007	—.006	—.005	—.005	—.004	—.003	—.003	—.002	—.001
80	—.001	—.001	.000	.000	+.001	+.001	+.001	+.002	+.002	+.002
90	+.002	+.002	+.002	+.002	+.002	+.002	+.001	+.001	+.001	.000
100	.000									

TABLE 236. (Hydrogen — 16^{III}), (Hydrogen — 59^{III}).

	—5°	—10°	—15°	—20°	—25°	—30°	—35°
$t_H - t_{16}$	+0.04°	+0.08°	+0.13°	+0.19°	+0.25°	+0.32°	+0.40°
$t_H - t_{59}$	+0.02°	+0.04°	+0.07°	+0.10°	+0.14°	+0.18°	+0.23°

All compiled from Landolt-Börnstein-Meyerhoffer's Physikalisch-chemische Tabellen.

AIR AND MERCURY THERMOMETERS.

TABLE 237. $t_{AIR} - t_{Hg}$. (Air − 16^{III}.)

°C.	0°	1°	2°	3°	4°	5°	6°	7°	8°	9°
0	.000	−.006	−.012	−.017	−.022	−.027	−.032	−.037	−.041	−.045
10	−.049	−.053	−.057	−.061	−.065	−.068	−.071	−.074	−.077	−.080
20	−.083	−.086	−.089	−.091	−.093	−.095	−.097	−.099	−.101	−.102
30	−.103	−.104	−.105	−.106	−.107	−.108	−.109	−.110	−.110	−.110
40	−.110	−.110	−.111	−.111	−.110	−.110	−.110	−.109	−.109	−.108
50	−.107	−.107	−.106	−.105	−.104	−.103	−.102	−.101	−.100	−.098
60	−.096	−.095	−.093	−.092	−.090	−.088	−.086	−.084	−.082	−.080
70	−.078	−.076	−.074	−.072	−.070	−.067	−.065	−.062	−.060	−.057
80	−.054	−.052	−.049	−.047	−.044	−.041	−.039	−.036	−.034	−.031
90	−.028	−.025	−.023	−.020	−.017	−.014	−.011	−.009	−.006	−.003
100	.000	+.003	+.006	+.008	+.011	+.014	+.017	+.019	+.022	+.025
110	+.028	+.030	+.033	+.035	+.038	+.041	+.043	+.046	+.048	+.050
120	+.053	+.055	+.057	+.060	+.062	+.064	+.066	+.068	+.070	+.072
130	+.074	+.076	+.078	+.080	+.081	+.083	+.084	+.086	+.087	+.089
140	+.090	+.091	+.092	+.093	+.094	+.095	+.096	+.096	+.097	+.097
150	+.098	+.098	+.098	+.099	+.099	+.099	+.098	+.098	+.098	+.097
160	+.097	+.096	+.095	+.094	+.093	+.092	+.090	+.089	+.088	+.086
170	+.084	+.082	+.080	+.078	+.076	+.073	+.071	+.068	+.065	+.062
180	+.059	+.055	+.052	+.048	+.045	+.041	+.037	+.033	+.028	+.023
190	+.019	+.014	+.009	+.004	−.001	−.007	−.013	−.019	−.025	−.031
200	−.038	−.045	−.051	−.058	−.066	−.073	−.080	−.088	−.096	−.105
210	−.113	−.122	−.130	−.139	−.148	−.158	−.168	−.177	−.187	−.198
220	−.208	−.219	−.230	−.241	−.252	−.264	−.275	−.287	−.300	−.312
230	−.325	−.338	−.351	−.365	−.378	−.392	−.407	−.421	−.436	−.450
240	−.466	−.481	−.497	−.513	−.529	−.546	−.562	−.579	−.597	−.614
250	−.632	−.650	−.668	−.687	−.706	−.725	−.745	−.765	−.785	−.805
260	−.825	−.846	−.867	−.889	−.911	−.933	−.955	−.978	−1.001	−1.025
270	−1.048	−1.072	−1.096	−1.121	−1.146	−1.171	−1.196	−1.222	−1.248	−1.274
280	−1.301	−1.328	−1.356	−1.384	−1.412	−1.440	−1.469	−1.498	−1.528	−1.558
290	−1.588	−1.618	−1.649	−1.680	−1.711	−1.743	−1.776	−1.808	−1.841	−1.874
300	−1.908									

TABLE 238. $t_{AIR} - t_{Hg}$. (Air − 59^{III}.)

°C.	0°	1°	2°	3°	4°	5°	6°	7°	8°	9°
100	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
110	.000	.000	.000	−.001	−.001	−.001	−.001	−.001	−.002	−.002
120	−.002	−.002	−.002	−.002	−.002	−.003	−.003	−.003	−.004	−.004
130	−.004	−.004	−.005	−.005	−.006	−.006	−.006	−.007	−.007	−.008
140	−.008	−.008	−.009	−.009	−.010	−.010	−.011	−.011	−.012	−.012
150	−.013	−.013	−.014	−.015	−.016	−.016	−.016	−.017	−.018	−.019
160	−.019	−.020	−.021	−.021	−.022	−.023	−.024	−.025	−.026	−.027
170	−.028	−.029	−.030	−.031	−.032	−.033	−.034	−.035	−.037	−.038
180	−.039	−.040	−.041	−.043	−.044	−.045	−.046	−.048	−.049	−.051
190	−.052	−.053	−.055	−.056	−.057	−.059	−.060	−.062	−.064	−.066
200	−.067									

GAS, MERCURY, ALCOHOL, TOLUOL, PETROLETHER, PENTANE, AND PLATINUM-RESISTANCE THERMOMETERS.

TABLE 239. $t^H - t_M$ (Hydrogen-Mercury).

Temperature, C.	Thuringer Glass.*	Verre dur. Tonnelot.†	Resistance Glass.*	English Crystal Glass.*	Choisy-le-Roi.*	122^{III}.*	Nitrogen Thermometer. $T_H - T_N$.†	CO_2 Thermometer. $T_H - T_{CO_2}$.†
°	°	°	°	°	°	°	°	°
0	.000	.000	.000	.000	.000	.000	.000	.000
10	—.075	—.052	—.066	—.008	—.007	—.005	—.006	—.025
20	—.125	—.085	—.108	—.001	—.004	—.006	—.010	—.043
30	—.156	—.102	—.131	+.017	+.004	—.002	—.011	—.054
40	—.168	—.107	—.140	+.037	+.014	+.001	—.011	—.059
50	—.166	—.103	—.135	+.057	+.025	+.004	—.009	—.059
60	—.150	—.090	—.119	+.073	+.033	+.008	—.005	—.053
70	—.124	—.072	—.095	+.079	+.037	+.009	—.001	—.044
80	—.088	—.050	—.068	+.070	+.032	+.007	+.002	—.031
90	—.047	—.026	—.034	+.046	+.022	+.006	+.003	—.016
100	.000	.000	.000	.000	.000	.000	.000	.000

* Schlösser, Zt. Instrkde. 21, 1901. † Chappuis, Trav. et mém. du Bur. Intern. des Poids et Mes. 6, 1888.

TABLE 240.—Comparison of Air and High Temperature Mercury Thermometers.

Comparison of the air thermometer with the high temperature mercury thermometer, filled under pressure and made of 59^{III} glass.

Air.	59^{III}.	Air.	59^{III}.
°	°	°	°
0	0.	375	385.4
100	100.	400	412.3
200	200.4	425	440.7
300	304.1	450	469.1
325	330.9	475	498.0
350	358.1	500	527.8

Mahlke, Wied. Ann. 1894.

TABLE 241.—Comparison of Hydrogen and Other Thermometers.

Comparison of the hydrogen thermometer with the toluol, alcohol, petrolether, and pentane thermometers (verre dur).

Hydrogen.	Toluol.*	Alcohol I.*	Alcohol II.*	Petrolether.†	Pentane.‡
°	°	°	°	°	°
0	0.00	0.00	0.00	–	0.00
—10	—8.54	—9.31	—9.44	–	—9.03
—20	—16.90	—18.45	—18.71	–	—17.87
—30	—25.10	—27.44	—27.84	–	—26.55
—40	—33.15	—36.30	—36.84	–	—35.04
—50	—41.08	—45.05	—45.74	—42.6	—43.36
—60	—48.90	—53.71	—54.55	–	—51.50
—70	—56.63	—62.31	—63.31	–	—59.46
—100	–	–	–	—80.2	—82.28
—150	–	–	–	—113.0	—116.87
—200	–	–	–	—140.7	—146.84

* Chappuis, Arch. sc. phys. (3) 18, 1892. † Holborn, Ann. d. Phys. (4) 6, 1901. ‡ Rothe, unpublished.
All compiled from Landolt-Börnstein-Meyerhoffer's Physikalisch-chemische Tabellen.

CORRECTION FOR TEMPERATURE OF MERCURY IN THERMOMETER STEM.

The Stem Correction is proportional to $n\beta(T-t)$: where n is the number of degrees in the exposed stem; β is the apparent coefficient of expansion of mercury in the glass; T is the measured temperature; and t is the mean temperature of the exposed stem determined by another thermometer, exposed some 10 cm. from, and at about half the height of, the exposed stem of the first.

For temperatures up to 100°C, the value of β is for:

Jena glass XVI^{III} or Greiner and Friedrich resistance glass, $\frac{1}{6300}$ or 0.000159;

Jena glass 59^{III}, $\frac{1}{6100}$ or 0.000164.

At 100° the correction is in round numbers 0.01° for each degree of the exposed stem; at 200° 0.02°; and for higher temperatures proportionately greater. At 500° it may amount to 0.07° for each exposed degree.

Tables 242–244 are taken from Rimbach, Zeitschrift für Instrumentenkunde, 10, 153, 1890, and apply to thermometers of Jena or of resistance glass.

TABLE 242.—Stem Correction for Thermometer of Jena Glass (0°-360° C.).

Degree length 0.9 to 1.1 mm; t = the observed temperature; t' = that of the surrounding air 1 dm. away; n = the length of the exposed thread.

CORRECTION TO BE ADDED TO THE READING t.										
n	$t-t'$									
	70°	80°	90°	100°	120°	140°	160°	180°	200°	220°
10	0.01	0.01	0.03	0.04	0.07	0.10	0.13	0.17	0.19	0.21
20	0.08	0.12	0.14	0.19	0.25	0.28	0.32	0.40	0.49	0.54
30	0.25	0.28	0.32	0.36	0.42	0.48	0.54	0.66	0.78	0.87
40	0.30	0.35	0.41	0.48	0.60	0.67	0.77	0.92	1.08	1.20
50	0.41	0.46	0.52	0.59	0.79	0.89	0.98	1.16	1.38	1.53
60	0.52	0.60	0.68	0.79	0.99	1.11	1.23	1.46	1.70	1.87
70	0.63	0.74	0.85	0.98	1.20	1.32	1.45	1.70	1.99	2.21
80	0.75	0.87	1.01	1.15	1.38	1.53	1.70	1.98	2.29	2.54
90	0.87	0.99	1.13	1.28	1.62	1.82	1.94	1.25	2.60	2.89
100	0.98	1.12	1.29	1.47	1.82	2.03	2.20	2.55	2.92	3.24
120	–	–	–	1.88	2.28	2.49	2.68	3.13	3.59	3.96
140	–	–	–	–	2.75	2.97	3.22	3.75	4.24	4.69
160	–	–	–	–	–	3.35	3.80	4.35	4.92	5.45
180	–	–	–	–	–	–	4.37	4.99	5.63	6.22
200	–	–	–	–	–	–	–	5.68	6.34	6.98
220	–	–	–	–	–	–	–	–	7.05	7.82

CORRECTION FOR TEMPERATURE OF MERCURY IN THERMOMETER STEM (*continued*).

TABLE 243. — Stem Correction for Thermometer of Jena Glass (0°-360° C).

Degree length 1 to 1.6 mm.; t = the observed temperature; t' = that of the surrounding air one dm. away; n = the length of the exposed thread.

Correction to be added to Thermometer Reading.*											
n	$t-t'$										n
	70°	80°	90°	100°	120°	140°	160°	180°	200°	220°	
10°	0.02	0.03	0.05	0.07	0.11	0.17	0.21	0.27	0.33	0.38	**10°**
20	0.13	0.15	0.18	0.22	0.29	0.38	0.46	0.53	0.61	0.67	20
30	0.24	0.28	0.33	0.39	0.48	0.59	0.70	0.78	0.88	0.97	30
40	0.35	0.41	0.48	0.56	0.68	0.82	0.94	1.04	1.16	1.28	40
50	0.47	0.53	0.62	0.72	0.88	1.03	1.17	1.31	1.44	1.59	**50**
60	0.57	0.66	0.77	0.89	1.09	1.25	1.42	1.58	1.74	1.90	60
70	0.69	0.79	0.92	1.06	1.30	1.47	1.67	1.86	2.04	2.23	70
80	0.80	0.91	1.05	1.21	1.52	1.71	1.94	2.15	2.33	2.55	80
90	0.91	1.04	1.19	1.38	1.73	1.96	2.20	2.42	2.64	2.89	**90**
100	1.02	1.18	1.35	1.56	1.97	2.18	2.45	2.70	2.94	3.23	100
110	–	–	–	1.78	2.19	2.43	2.70	2.98	3.26	3.57	110
120	–	–	–	1.98	2.43	2.69	2.95	3.26	3.58	3.92	120
130	–	–	–	–	2.68	2.94	3.20	3.56	3.89	4.28	**130**
140	–	–	–	–	2.92	3.22	3.47	3.86	4.22	4.64	140
150	–	–	–	–	–	–	3.74	4.15	4.56	5.01	150
160	–	–	–	–	–	–	4.00	4.46	4.90	5.39	160
170	–	–	–	–	–	–	4.27	4.76	5.24	5.77	**170**
180	–	–	–	–	–	–	4.54	5.07	5.59	6.15	180
190	–	–	–	–	–	–	–	5.38	5.95	6.54	190
200	–	–	–	–	–	–	–	5.70	6.30	6.94	200
210	–	–	–	–	–	–	–	–	6.68	7.35	**210**
220	–	–	–	–	–	–	–	–	7.04	7.75	220

* See Hovestadt's "Jena Glass" (translated by J. D. and A. Everett) for data on changes of thermometer zeros.

TABLE 244. — Stem Correction for a so-called Normal Thermometer of Jena Glass (0°-100° C).

Divided into tenth degrees; degree length about 4 mm.

Correction to be added to the Reading t.												
n	$t-t'$											
	30°	35°	40°	45°	50°	55°	60°	65°	70°	75°	80°	85°
10	0.04	0.04	0.05	0.05	0.05	0.06	0.06	0.07	0.08	0.09	0.10	0.10
20	0.12	0.12	0.13	0.14	0.15	0.16	0.17	0.18	0.19	0.20	0.22	0.23
30	0.21	0.22	0.23	0.24	0.25	0.25	0.27	0.29	0.31	0.33	0.35	0.37
40	0.28	0.29	0.31	0.33	0.35	0.37	0.39	0.41	0.43	0.45	0.48	0.51
50	0.36	0.38	0.40	0.42	0.44	0.46	0.48	0.50	0.53	0.57	0.61	0.65
60	0.45	0.48	0.51	0.53	0.55	0.57	0.60	0.63	0.66	0.69	0.73	0.78
70	–	–	–	–	–	0.66	0.69	0.71	0.75	0.81	0.87	0.92
80	–	–	–	–	–	–	0.76	0.81	0.87	0.93	1.00	1.06
90	–	–	–	–	–	–	–	0.92	0.99	1.06	1.13	1.20
100	–	–	–	–	–	–	–	–	1.10	1.18	1.26	1.34

RADIATION CONSTANTS.

TABLE 245. — Radiation Formula and Constants for Perfect Radiator.

The radiation per sq. cm. from a "black body" (exclusive of convection losses) at the temperature $T°$ (absolute, C) to one at $t°$ is equal to

$$J = \sigma (T^4 - t^4) \quad \text{(Stefan-Boltzmann)};$$

where $\sigma = 1.277 \times 10^{-12}$ gramme-calories per second per sq. centimetre.
$= 7.66 \times 10^{-11}$ " " " minute " " "
$= 5.32 \times 10^{-12}$ watts per sq. centimetre.

The distribution of this energy in the spectrum is represented by Planck's formula:

$$J_\lambda = C_1 \lambda^{-5} \left[e^{\frac{C_2}{\lambda T}} - 1 \right]^{-1}$$

where J_λ is the intensity of the energy at the wave-length λ (λ expressed in microns, μ) and e is the base of the Napierian logarithms. From Kurlbaum's value of the difference of the total energy radiated from black bodies at 100° C and 0° C, $J_{100} - J_0 = 0.0731$ watts per square centimetre (whence the above value of σ) and $\lambda_{max} T = 2930$ (the mean of Paschen's and Lummer's values), the following constants have been calculated (see Planck, Ann. d. Phys. 4, p. 562, 1901):

$C_1 = 8.813 \times 10^{3}$ for J in $\frac{gram.\ cal.}{sec.\ cm.^2} = 3.688 \times 10^{4}$ for J in $\frac{watts}{cm.^2}$

$C_2 = 14550$ for λ in microns (μ)

$J_{max} = 2.869 \times 10^{-16}\, T^5$ for J in $\frac{gram.\ cal.}{sec.\ cm.^2} = 1.200 \times 10^{-15} T^5$ for J in $\frac{watts}{cm.^2}$

$\lambda_{max} T = 2930$ for λ in microns (μ).

TABLE 246. — Radiation in Gramme-Calories per 24 Hours from a Perfect Radiator at t° C to an absolutely Cold Space (−273° C).

Computed from the Stefan-Boltzmann formula (Ekholm, Met. Z 1902).

t° C	J	t° C	J	t° C	J	t° C	J	t° C	J	t° C	J
−273	0	−120	60	−10	528	+12	728	+34	980	+56	1292
−220	1	−110	78	−8	544	+14	748	+36	1006	+58	1324
−210	2	−100	99	−6	561	+16	769	+38	1032	+60	1356
−200	3	−90	124	−4	578	+18	791	+40	1059	+70	1530
−190	5	−80	153	−2	595	+20	813	+42	1086	+80	1713
−180	8	−70	187	0	613	+22	836	+44	1114	+90	1916
−170	12	−60	227	+2	631	+24	859	+46	1142	+100	2134
−160	18	−50	273	+4	649	+26	882	+48	1171	+200	5519
−150	25	−40	324	+6	668	+28	906	+50	1201	+1000	290×10^3
−140	35	−30	385	+8	688	+30	930	+52	1231	+2000	294×10^4
−130	46	−20	452	+10	708	+32	955	+54	1261	+5000	852×10^5

TABLE 247. — Values of J_λ for Various Temperatures Centigrade.

Ekholm, Met. Z. 1902, used $C_1 = 8346 \times 10$ and $C_2 = 14349$, and for the unit of time the day.
For 10°, the values for J_λ have been multiplied by 10, for the other temperatures by 100.

λ	T = 100° C	30° C	15° C	0° C	−30° C	−80° C	λ	100° C	30° C	15° C	0° C	−30° C	−80° C
μ							μ						
2	1	0	0	0	0	0	18	511	2961	2557	2175	1491	623
3	80	41	18	7	1	0	19	443	2626	2281	1954	1363	594
4	469	508	272	138	27	1	20	386	2329	2034	1754	1242	561
5	1047	1777	1085	628	172	8	21	337	2068	1816	1574	1129	527
6	1526	3464	2296	1454	493	39	22	295	1840	1622	1413	1026	494
7	1768	4954	3481	2353	931	105	23	259	1639	1448	1270	931	460
8	1810	5928	4352	3088	1372	203	24	228	1462	1298	1141	846	428
9	1724	6382	4834	3646	1730	316	25	202	1307	1165	1028	768	398
10	1573	6386	4979	3781	1971	426	26	179	1170	1047	926	698	369
11	1398	6127	4833	3798	2098	520	28	142	947	850	757	579	317
12	1225	5712	4633	3676	2114	592	30	114	771	696	623	482	272
13	1063	5222	4300	3467	2090	640	40	44	311	285	259	209	130
14	918	4713	3930	3215	2004	666	50	20	146	135	124	102	67
15	792	4220	3556	2944	1889	673	60	10	77	72	66	55	38
16	683	3759	3198	2674	1760	663	80	4	27	25	24	20	14
17	590	3340	2862	2417	1626	649	100	2	12	11	10	9	7

COOLING BY RADIATION AND CONVECTION.

TABLE 248. — At Ordinary Pressures.

ling to McFarlane* the rate of loss of heat by a sphere ed in the centre of a spherical enclosure which has a kened surface, and is kept at a constant temperature of t 14° C, can be expressed by the equations

$$e = .000238 + 3.06 \times 10^{-6}t - 2.6 \times 10^{-6}\beta,$$

n the surface of the sphere is blackened, or

$$e = .000168 + 1.98 \times 10^{-6}t - 1.7 \times 10^{-6}\beta,$$

n the surface is that of polished copper. In these equa-, e is the amount of heat lost in c. g. s. units, that is, uantity of heat, small calories, radiated per second per re centimetre of surface of the sphere, per degree differ- of temperature t, and t is the difference of temperature een the sphere and the enclosure. The medium through h the heat passed was moist air. The following table the results.

fer- e of pera- re	Value of e.		Ratio.
	Polished surface.	Blackened surface.	
5	.000178	.000252	.707
0	.000186	.000266	.699
5	.000193	.000279	.692
0	.000201	.000289	.695
5	.000207	.000298	.694
0	.000212	.000306	.693
5	.000217	.000313	.693
0	.000220	.000319	.693
5	.000223	.000323	.690
0	.000225	.000326	.690
5	.000226	.000328	.690
0	.000226	.000328	.690

TABLE 249. — At Different Pressures.

Experiments made by J. P. Nicol in Tait's Laboratory show the effect of pressure of the enclosed air on the rate of loss of heat. In this case the air was dry and the enclosure kept at about 8° C.

Polished surface.		Blackened surface.	
t	et	t	et
Pressure 76 cms. of Mercury.			
63.8	.00987	61.2	.01746
57.1	.00862	50.2	.01360
50.5	.00736	41.6	.01078
44.8	.00628	34.4	.00860
40.5	.00562	27.3	.00640
34.2	.00438	20.5	.00455
29.6	.00378	–	–
23.3	.00278	–	–
18.6	.00210	–	–
Pressure 10.2 cms. of Mercury.			
67.8	.00492	62.5	.01298
61.1	.00433	57.5	.01158
55	.00383	53.2	.01048
49.7	.00340	47.5	.00898
44.9	.00302	43.0	.00791
40.8	.00268	28.5	.00490
Pressure 1 cm. of Mercury.			
65	.00388	62.5	.01182
60	.00355	57.5	.01074
50	.00286	54.2	.01003
40	.00219	41.7	.00726
30	.00157	37.5	.00639
23.5	.00124	34.0	.00569
–	–	27.5	.00446
–	–	24.2	.00391

* "Proc. Roy. Soc." 1872.
† "Proc. Roy. Soc." Edinb. 1869.
See also Compan, Annal. de chi. et phys. 26, p. 526.

COOLING BY RADIATION AND CONVECTION.

TABLE 250. — Cooling of Platinum Wire in Copper Envelope.

Bottomley gives for the radiation of a bright platinum wire to a copper envelope when the space between is at the highest vacuum attainable the following numbers: —

$t = 408°$ C., $et = 378.8 \times 10^{-4}$, temperature of enclosure 16° C.
$t = 505°$ C., $et = 726.1 \times 10^{-4}$, " " 17° C.

It was found at this degree of exhaustion that considerable relative change of the vacuum produced very small change of the radiating power. The curve of relation between degree of vacuum and radiation becomes asymptotic for high exhaustions. The following table illustrates the variation of radiation with pressure of air in enclosure.

Temp. of enclosure 16° C., $t = 408°$ C.		Temp. of enclosure 17° C., $t = 505°$ C.	
Pressure in mm.	et	Pressure in mm.	et
740.	8137.0×10^{-4}	0.094	1688.0×10^{-4}
440.	7971.0 "	.053	1255.0 "
140.	7875.0 "	.034	1126.0 "
42.	7591.0 "	.013	920.4 "
4.	6036.0 "	.0046	831.4 "
0.444	2683.0 "	.00052	767.4 "
.070	1045.0 "	.00019	746.4 "
.034	727.3 "	Lowest reached but not measured	726.1 "
.012	539.2 "		
.0051	436.4 "		
.00007	378.8 "		

TABLE 251. — Effect of Pressure on Loss of Heat at Different Temperatures.

The temperature of the enclosure was about 15° C. The numbers give the total radiation in therms per square centimetre per second.

Temp. of wire in C°.	Pressure in mm.				
	10.0	1.0	0.25	0.025	About 0.1 M.
100°	0.14	0.11	0.05	0.01	0.005
200	.31	.24	.11	.02	.0055
300	.50	.38	.18	.04	.0105
400	.75	.53	.25	.07	.025
500	–	.69	.33	.13	.055
600	–	.85	.45	.23	.13
700	–	–	–	.37	.24
800	–	–	–	.56	.40
900	–	–	–	–	.61

NOTE. — An interesting example (because of its practical importance in electric lighting) of the effect of difference of surface condition on the radiation of heat is given on the authority of Mr. Evans and himself in Bottomley's paper. The energy required to keep up a certain degree of incandescence in a lamp when the filament is dull black and when it is "flashed" with coating of hard bright carbon, was found to be as follows: —

Dull black filament, 57.9 watts.
Bright " " 39.8 watts.

PROPERTIES OF STEAM.

Metric Measure.

The temperature Centigrade and the absolute temperature in degrees Centigrade, together with other data for steam or water vapor stated in the headings of the columns, are here given. The quantities of heat are in therms or calories according as the gramme or the kilogramme is taken as the unit of mass.

Temp. C.	Absolute temp.	Pressure in mm. of mercury.	Pressure in grammes per sq. centimetre $= p$.	Pressure in atmospheres.	Total heat of evaporation from 0° at $p = H$.	Heat of liquid $= h$.	Heat of evaporation $= H - h$.	Outer latent or external-work heat $= Ap v$.*	Total heat of steam $= H - Ap v$.	Inner latent or internal-work heat $= H - (h + Ap v)$.	Litres per gramme, or cubic metres per kilog. $= v$.	Ratio of inner latent heat to volume of steam.†
0°	273	4.60	6.25	0.006	606.5	0.00	606.5	31.07	575.4	575.4	210.66	2.732
5	278	6.53	8.88	.009	608.0	5.00	603.0	31.47	576.5	571.5	150.23	3.805
10	283	9.17	12.47	.012	609.5	10.00	599.5	31.89	577.7	567.7	108.51	5.231
15	288	12.70	17.27	.017	611.1	15.00	596.0	32.32	578.8	563.7	79.35	7.104
20	293	17.39	23.64	.023	612.6	20.01	592.6	32.75	579.8	559.8	78.72	9.532
25	298	23.55	32.02	0.031	614.1	25.02	589.1	33.20	580.9	555.9	43.96	12.64
30	303	31.55	42.89	.042	615.6	30.03	585.6	33.66	582.0	552.0	33.27	16.59
35	308	41.83	56.87	.055	617.2	35.04	582.1	34.12	583.1	548.2	25.44	21.54
40	313	54.91	74.65	.072	618.7	40.05	587.6	34.59	584.1	544.1	19.64	27.70
45	318	71.39	97.06	.094	620.2	45.07	575.1	35.06	585.2	540.1	15.31	35.26
50	323	91.98	125.0	0.121	621.7	50.09	571.7	35.54	586.2	536.1	12.049	44.49
55	328	117.47	159.7	.155	623.3	55.11	568.2	36.02	587.2	532.1	9.561	55.65
60	333	148.79	202.3	.196	624.8	60.13	564.7	36.51	588.3	528.1	7.653	69.02
65	338	186.94	254.2	.246	626.3	65.17	561.1	37.00	589.3	524.2	6.171	84.94
70	343	233.08	316.9	.306	627.8	70.20	557.6	37.48	590.4	520.2	5.014	103.75
75	348	288.50	392.3	0.380	629.4	75.24	554.1	37.96	591.4	516.2	4.102	125.8
80	353	354.62	482.1	.446	630.9	80.28	550.6	38.42	592.5	512.2	3.379	151.6
85	358	433.00	588.7	.570	632.4	85.33	547.1	38.88	593.5	508.2	2.800	181.5
90	363	525.39	714.4	.691	633.9	90.38	543.6	39.33	594.6	504.2	2.334	216.0
95	368	633.69	861.7	.834	635.5	95.44	540.0	39.76	595.7	500.3	1.957	255.7
100	373	760.00	1033.	1.000	637.0	100.5	536.5	40.20	596.8	496.3	1.6496	300.8
105	378	906.41	1232.	.193	638.5	105.6	533.0	40.63	597.9	492.3	1.3978	352.2
110	383	1075.4	1462.	.415	640.0	110.6	529.4	41.05	599.0	488.4	1.1903	410.3
115	388	1269.4	1726.	.670	641.6	115.7	525.8	41.46	600.1	484.4	1.0184	475.6
120	393	1491.3	2027.	.962	643.1	120.8	522.3	41.86	601.2	480.4	0.8752	549.0
125	398	1743.9	2371.	2.295	644.6	125.9	518.7	42.25	602.4	476.5	0.7555	630.7
130	403	2030.3	2760.	2.671	646.1	131.0	515.1	42.63	603.5	472.5	0.6548	721.6
135	408	2353.7	3200.	3.097	647.7	136.1	511.6	43.01	604.7	468.6	0.5698	822.3
140	413	2717.6	3695.	3.576	649.2	141.2	508.0	43.38	605.8	464.6	0.4977	933.5
145	418	3125.6	4249.	4.113	650.7	146.3	504.4	43.73	607.0	460.7	0.4363	1055.7
150	423	3581.2	4869.	4.712	652.2	151.5	500.8	44.09	608.2	456.7	0.3839	1190.
155	428	4088.6	5589.	5.380	653.8	156.5	497.2	44.43	609.3	452.8	0.3388	1336.
160	433	4651.6	6324.	6.120	655.3	161.7	493.5	44.76	610.5	448.8	0.3001	1496.
165	438	5274.5	7171.	6.940	656.8	166.9	489.9	45.09	611.7	444.8	0.2665	1669.
170	443	5961.7	8105.	7.844	658.3	172.0	486.3	45.40	612.9	440.9	0.2375	1856.
175	448	6717.4	9133.	8.839	659.9	177.2	482.7	45.71	614.2	436.9	0.2122	2059.
180	453	7546.4	10260.	9.929	661.4	182.4	479.0	46.01	615.4	433.0	0.1901	2277.
185	458	8453.2	11490.	11.123	662.9	187.6	475.3	46.30	616.6	429.0	0.1708	2512.
190	463	9442.7	12838.	12.425	664.4	192.8	471.7	46.59	617.9	425.0	0.1538	2763.
195	468	10520.	14303.	13.842	666.0	198.0	468.0	46.86	619.1	421.1	0.1389	3031.
200	473	11689.	15892.	15.380	667.5	203.2	464.3	47.13	620.4	417.1	0.1257	3318.

* Where A is the reciprocal of the mechanical equivalent of the thermal unit.

† $= \frac{H - (h + Ap v)}{v} = \frac{\text{internal-work pressure}}{\text{mechanical equivalent of heat}}$. Where v is taken in litres the pressure is given per square decimetre, and where v is taken in cubic metres the pressure is given per square metre, — the mechanical equivalent being that of the therm and the kilogramme-degree or calorie respectively.

TABLE 253.

PROPERTIES OF STEAM.

British Measure.

The quantities given in the different columns of this table are sufficiently explained by the headings. The a
tion B. T. U. stands for British thermal units. With the exception of column 3, which was calculated
table, the data are taken from a table given by Dwelshauvers-Dery (Trans. Am. Soc. Mech. Eng. vol. xi.).

Pressure in pounds per square inch.	Pressure in pounds per square foot.	Pressure in atmospheres.	Temp. in degrees Fahr.	Volume per pound in cubic feet.	Weight per cubic foot in pounds.	Heat of water per pound in B. T. U.	Internal latent heat per pound of steam in B. T. U.	External latent heat per pound of steam in B. T. U.	Total latent heat per pound of steam in B. T. U.	Total heat per
1	144	0.068	102.0	334.23	0.0030	70.1	980.6	62.34	1043.	11
2	288	.136	126.3	173.23	.0058	94.4	961.4	64.62	1026.	11
3	432	.204	141.6	117.98	.0085	109.9	949.2	66.58	1011.	11
4	576	.272	153.1	89.80	.0111	121.4	940.2	67.06	1007.	11
5	720	.340	162.3	72.50	.0137	130.7	932.8	67.89	1001.	11
6	864	0.408	170.1	61.10	0.0163	138.6	926.7	68.58	995.2	11
7	1008	.476	176.9	53.00	.0189	145.4	921.3	69.18	990.5	11
8	1152	.544	182.9	46.60	.0214	151.5	916.5	69.71	986.2	11
9	1296	.612	188.3	41.82	.0239	156.9	912.2	70.18	982.4	11
10	1440	.680	193.2	37.80	.0264	161.9	908.3	70.61	979.0	11
11	1584	0.748	197.8	34.61	0.0289	166.5	904.8	70.99	975.8	11
12	1728	.816	202.0	31.90	.0314	170.7	901.5	71.34	972.8	11
13	1872	.884	205.9	29.58	.0338	174.7	898.4	71.68	970.0	11
14	2016	.952	209.5	27.59	.0362	178.4	895.4	72.00	967.4	11
15	2160	1.020	213.0	25.87	.0387	181.9	892.7	72.29	965.0	11
16	2304	1.088	216.3	24.33	0.0411	185.2	890.1	72.57	962.7	11
17	2448	.156	219.4	22.98	.0435	188.4	887.6	72.82	960.4	11
18	2592	.224	222.4	21.78	.0459	191.4	885.3	73.07	958.3	11
19	2736	.292	225.2	20.70	.0483	194.3	883.1	73.30	956.3	11
20	2880	.360	227.9	19.72	.0507	197.0	880.9	73.53	954.4	11
21	3024	1.429	230.5	18.84	0.0531	199.7	878.8	73.74	952.6	11
22	3168	.497	233.0	18.03	.0554	202.2	876.8	73.94	950.8	11
23	3312	.565	235.4	17.30	.0578	204.7	874.9	74.13	949.1	11
24	3456	.633	237.7	16.62	.0602	207.0	873.1	74.32	947.4	11
25	3600	.701	240.0	15.99	.0625	209.3	871.3	74.51	945.8	11
26	3744	1.769	242.2	15.42	0.0649	211.5	869.6	74.69	944.3	11
27	3888	.837	244.3	14.88	.0672	213.7	867.9	74.85	942.8	11
28	4032	.905	246.3	14.38	.0695	215.7	866.3	75.01	941.3	11
29	4176	.973	248.3	13.91	.0619	217.8	864.7	75.17	939.9	11
30	4320	2.041	250.2	13.48	.0742	219.7	863.2	75.33	938.5	11
31	4464	2.109	252.1	13.07	0.0765	221.6	861.7	75.47	937.2	11
32	4608	.177	253.9	12.68	.0788	223.5	860.3	75.61	935.9	11
33	4752	.245	255.7	12.32	.0811	225.3	858.9	75.76	934.6	11
34	4896	.313	257.5	11.98	.0835	227.1	857.5	75.89	933.4	11
35	5040	.381	259.2	11.66	.0858	228.8	856.1	76.02	932.1	11
36	5184	2.449	260.8	11.36	0.0881	230.5	854.8	76.16	931.0	11
37	5328	.517	262.5	11.07	.0903	232.2	853.5	76.28	929.8	11
38	5472	.585	264.0	10.79	.0926	233.8	852.3	76.40	928.7	11
39	5616	.653	265.6	10.53	.0949	235.4	851.0	76.52	927.6	11
40	5760	.722	267.1	10.29	.0972	236.9	849.8	76.63	926.5	11
41	5904	2.789	268.6	10.05	0.0995	238.5	848.7	76.75	925.4	11
42	6048	.857	270.1	9.83	.1018	239.9	847.5	76.86	924.4	11
43	6192	.925	271.5	9.61	.1040	241.4	846.4	76.97	923.3	11
44	6336	.993	272.9	9.41	.1063	242.9	845.2	77.07	922.3	11
45	6480	3.061	274.3	9.21	.1086	244.3	844.1	77.18	921.3	11
46	6624	3.129	275.6	9.02	0.1108	245.6	843.1	77.29	920.4	11
47	6768	.197	277.0	8.84	.1131	247.0	842.0	77.39	919.4	11
48	6912	.265	278.3	8.67	.1153	248.3	841.0	77.49	918.5	11
49	7056	.333	279.6	8.50	.1176	249.7	840.0	77.58	917.5	11

TABLE 253 (*continued*).

PROPERTIES OF STEAM.

British Measure.

Pressure in pounds per square inch.	Pressure in pounds per square foot.	Pressure in atmospheres.	Temp. in degrees Fahr.	Volume per pound in cubic feet.	Weight per cubic foot in pounds.	Heat of water per pound in B. T. U.	Internal latent heat per pound of steam in B. T. U.	External latent heat per pound of steam in B. T. U.	Total latent heat per pound of steam in B. T. U.	Total heat per pound of steam in B. T. U.
50	7200	3.401	280.8	8.34	0.1198	251.0	839.0	77.67	916.6	1167.6
51	7344	.469	282.1	8.19	.1221	252.2	838.0	77.76	915.7	1168.0
52	7488	.537	283.3	8.04	.1243	253.5	837.0	77.85	914.9	1168.3
53	7632	.605	284.5	7.90	.1266	254.7	836.0	77.94	914.0	1168.7
54	7776	.673	285.7	7.76	.1288	256.0	835.1	78.03	913.1	1169.1
55	7920	3.741	286.9	7.63	0.1310	257.1	834.2	78.12	912.3	1169.4
56	8064	.801	288.1	7.50	.1333	258.3	833.2	78.21	911.5	1169.8
57	8208	.878	289.2	7.38	.1355	259.5	832.3	78.29	910.6	1170.1
58	8352	.946	290.3	7.26	.1377	260.7	831.5	78.37	909.8	1170.5
59	8496	4.014	291.4	7.14	.1400	261.8	830.6	78.45	909.0	1170.8
60	8640	4.082	292.5	7.03	0.1422	262.9	829.7	78.53	908.2	1171.2
61	8784	.150	293.6	6.92	.1444	264.0	828.9	78.61	907.5	1171.5
62	8928	.218	294.7	6.82	.1466	265.1	828.0	78.68	906.7	1171.8
63	9072	.286	295.7	6.72	.1488	266.1	827.2	78.76	905.9	1172.1
64	9216	.354	296.7	6.62	.1511	267.2	826.4	78.83	905.2	1172.4
65	9360	4.422	297.8	6.52	0.1533	268.3	825.6	78.90	904.5	1172.8
66	9504	.490	298.8	6.43	.1555	269.3	824.8	78.97	903.7	1173.1
67	9648	.558	299.8	6.34	.1577	270.4	824.0	79.04	903.1	1173.4
68	9792	.626	300.1	6.25	.1599	271.4	823.2	79.11	902.3	1173.7
69	9936	.694	301.8	6.17	.1621	272.4	822.4	79.18	901.6	1174.0
70	10080	4.762	302.7	6.09	0.1643	273.4	821.6	79.25	900.9	1174.3
71	10224	.830	303.7	6.00	.1665	274.3	820.9	79.32	900.2	1174.6
72	10368	.898	304.6	5.93	.1687	275.3	820.1	79.39	899.5	1174.9
73	10512	.966	305.5	5.85	.1709	276.3	819.4	79.46	898.8	1175.1
74	10656	5.034	306.5	5.78	.1731	277.2	818.7	79.53	898.1	1175.4
75	10800	5.102	307.4	5.70	0.1753	278.2	817.9	79.59	897.5	1175.7
76	10944	.170	308.3	5.63	.1775	279.1	817.2	79.65	896.9	1176.0
77	11088	.238	309.2	5.57	.1797	280.0	816.5	79.71	896.2	1176.2
78	11232	.306	310.1	5.50	.1818	280.9	815.8	79.77	895.6	1176.5
79	11376	.374	310.9	5.43	.1840	281.8	815.1	79.83	895.0	1176.8
80	11520	5.442	311.8	5.37	0.1862	282.7	814.4	79.89	894.3	1177.0
81	11664	.510	312.7	5.31	.1884	283.6	813.8	79.95	893.7	1177.3
82	11808	.578	313.5	5.25	.1906	284.5	813.0	80.01	893.1	1177.6
83	11952	.646	314.4	5.19	.1928	285.3	812.4	80.07	892.5	1177.8
84	12096	.714	315.2	5.13	.1949	286.2	811.7	80.13	891.9	1178.0
85	12240	5.782	316.0	5.07	0.1971	287.0	811.1	80.19	891.3	1178.3
86	11384	.850	316.8	5.02	.1993	287.9	810.4	80.25	890.7	1178.6
87	12528	.918	317.6	4.96	.2015	288.7	809.8	80.30	890.1	1178.9
88	12672	.986	318.4	4.91	.2036	289.5	809.2	80.35	889.5	1179.0
89	12816	6.054	319.2	4.86	.2058	290.4	808.5	80.40	888.9	1179.3
90	12960	6.122	320.0	4.81	0.2080	291.2	807.9	80.45	888.4	1179.5
91	13104	.190	320.8	4.76	.2102	292.0	807.3	80.50	887.8	1179.8
92	13248	.258	321.6	4.71	.2123	292.8	806.7	80.56	887.2	1180.0
93	13392	.327	322.4	4.66	.2145	293.6	806.1	80.61	886.7	1180.3
94	13536	.396	323.1	4.62	.2166	294.3	805.5	80.66	886.1	1180.5
95	13680	6.463	323.9	4.57	0.2188	295.1	804.9	80.71	885.6	1180.7
96	13824	.531	324.6	4.53	.2209	295.9	804.3	80.76	885.0	1180.9
97	13968	.599	325.4	4.48	.2231	296.7	803.7	80.81	884.5	1181.2
98	14112	.667	326.1	4.44	.2252	297.4	803.1	80.86	884.0	1181.4
99	14256	.735	326.8	4.40	.2274	298.2	802.5	80.91	883.4	1181.6

TABLE 253 (*continued*).

PROPERTIES OF STEAM.

British Measure.

Pressure in pounds per square inch.	Pressure in pounds per square foot.	Pressure in atmospheres.	Temp. in degrees Fahr.	Volume per pound in cubic feet.	Weight per cubic foot in pounds.	Heat of water per pound in B. T. U.	Internal latent heat per pound of steam in B. T. U.	External latent heat per pound of steam in B. T. U.	Total latent heat per pound of steam in B. T. U.	Total heat per pound of steam
100	14400	6.803	327.6	4.356	0.2295	298.9	802.0	80.95	882.9	1181.8
101	14544	.871	328.3	.316	.2317	299.7	801.4	81.00	882.4	1182.1
102	14688	.939	329.0	.276	.2338	300.4	800.8	81.05	881.9	1182.3
103	14832	7.007	329.7	.237	.2360	301.1	800.3	81.10	881.4	1182.5
104	14976	.075	330.4	.199	.2381	301.9	799.7	81.14	880.8	1182.7
105	15120	7.143	331.1	4.161	0.2403	302.6	799.2	81.18	880.3	1182.9
106	15264	.211	331.8	.125	.2424	303.3	798.6	81.23	879.8	1183.1
107	15408	.279	332.5	.088	.2446	304.0	798.1	81.27	879.3	1183.3
108	15552	.347	333.2	.053	.2467	304.7	797.5	81.31	878.8	1183.5
109	15696	.415	333.8	.018	.2489	305.4	797.0	81.36	878.3	1183.8
110	15840	7.483	334.5	3.984	0.2510	306.1	796.5	81.41	877.9	1184.0
111	15984	.551	335.2	.950	.2531	306.8	795.9	81.45	877.4	1184.2
112	16128	.619	335.8	.917	.2553	307.5	795.4	81.50	876.9	1184.4
113	16272	.687	336.5	.885	.2574	308.2	794.9	81.54	876.4	1184.6
114	16416	.757	337.2	.853	.2596	308.8	794.4	81 58	875.9	1184.8
115	16560	7.823	337.8	3.821	0.2617	309.5	793.8	81.62	875.5	1185.0
116	16704	.891	338.5	.790	.2638	310.2	793.3	81.66	875.0	1185.2
117	16848	.959	339.1	.760	.2660	310.8	792.8	81.70	874.5	1185.4
118	16992	8.027	339.7	.730	.2681	311.5	792.3	81.74	874.1	1185.6
119	17136	.095	340.4	.700	.2702	312.1	791.8	81.78	873.6	1185.7
120	17280	8.163	341.0	3.671	0.2724	312.8	791.3	81.82	873.2	1185.9
121	17424	.231	341.6	.643	.2745	313.4	790.8	81.86	872.7	1186.1
122	17568	.299	342.2	.615	.2766	314.1	790.3	81.90	872.2	1186.3
123	17712	.367	342.8	.587	.2787	314.7	789.9	81.94	871.8	1186.5
124	17856	.435	343.5	.560	.2809	315.3	789.4	81.98	871.4	11867
125	18000	8.503	344.1	3.534	0.2830	316.0	788.9	82.02	870.9	1186.9
126	18144	.571	344.7	.507	.2851	316.6	788.4	82.06	870.5	1187.1
127	18288	.639	345.3	.481	.2872	317.2	787.9	82.09	870.0	1187.2
128	18432	.708	345.9	.456	.2893	317.8	787.5	82.13	869.6	1187.4
129	18576	.776	346.5	.431	.2915	318.4	787.0	82.17	869.2	1187.6
130	18720	8.844	347.1	3.406	0.2936	319.0	786.5	82.21	868.7	1187.8
131	18864	.912	347.6	.382	.2957	319.7	786.1	82.25	868.3	1188.0
132	19008	.980	348.2	.358	.2978	320.3	785.6	82.28	867.9	1188.1
133	19152	9.048	348.8	.334	.2999	320.9	785.1	82.32	867.5	1188.3
134	19296	.116	349.4	.310	.3021	321.5	784.7	82.35	867.0	1188.5
135	19440	9.184	349.9	3.287	0.3042	322.1	784.2	82.38	866.6	1188.7
136	19584	.252	350.5	.265	.3063	322.6	783.8	82.42	866.2	1188.8
137	19728	.320	351.1	.424	.3084	323.2	783.3	82.45	865.8	1189.0
138	19872	.388	351.6	.220	.3105	323.8	782.9	82.49	865.4	1189.2
139	20016	.456	352.2	.199	.3126	324.4	782.4	82.52	865.0	1189.4
140	20160	9.524	352.8	3.177	0.3147	325.0	782.0	82.56	864.6	1189.5
141	20304	.592	353.3	.156	.3168	325.5	781.6	82.59	864.2	1189.7
142	20448	.660	353.9	.135	.3190	326.1	781.1	82.63	863.8	1189.9
143	20592	.728	354.4	.115	.3211	326.7	780.7	82.66	863.4	1190.0
144	20736	.796	355.0	.094	.3232	327.2	780.3	82.69	863.0	1190.2
145	20880	9.864	355.5	3.074	0.3253	327.8	779.8	82.72	862.6	1190.4
146	21024	.932	356.0	.054	.3274	328.4	779.4	82.75	862.2	1190.5
147	21168	10.000	356.6	.035	.3295	328.9	779.0	82.79	861.8	1190.7
148	21312	.068	357.1	.016	.3316	329.5	778.6	82.82	861.4	1190.9
149	21456	.136	357.6	.997	.3337	330.0	778.1	82.86	861.0	1191.0

TABLE 253 (*continued*).

PROPERTIES OF STEAM.

British Measure.

Pressure in pounds per square foot.	Pressure in atmospheres.	Temp. in degrees Fahr.	Volume per pound in cubic feet.	Weight per cubic foot in pounds.	Heat of water per pound in B. T. U.	Internal latent heat per pound of steam in B. T. U.	External latent heat per pound of steam in B. T. U.	Total latent heat per pound of steam in B. T. U.	Total heat per pound of steam in B. T. U.
21600	10.204	358.2	2.978	0.3358	330.6	777.7	82.89	860.6	1191.2
21744	.272	358.7	.960	.3379	331.1	777.3	82.92	860.2	1191.3
21888	.340	359.2	.941	.3400	331.6	776.9	82.95	859.9	1191.5
22032	.408	359.7	.923	.3421	332.2	776.5	82.98	859.5	1191.7
22176	.476	360.2	.906	.3442	332.7	776.1	83.01	859.1	1191.8
22320	10.544	360.7	2.888	0.3462	333.2	775.7	83.04	858.7	1192.0
22464	.612	361.3	.871	.3483	333.8	775.3	83.07	858.3	1192.1
22608	.680	361.8	.854	.3504	334.3	774.9	83.10	858.0	1192.3
22752	.748	362.3	.837	.3525	334.8	774.5	83.13	857.6	1192.4
22896	.816	362.8	.820	.3546	335.3	774.1	83.16	857.2	1192.6
23040	10.884	363.3	2.803	0.3567	335.9	773.7	83.19	856.9	1192.7
23184	.952	363.8	.787	.3588	336.4	773.3	83.22	856.5	1192.9
23328	11.020	364.3	.771	.3609	336.9	772.9	83.25	856.1	1193.0
23472	.088	364.8	.755	.3630	337.4	772.5	83.28	855.8	1193.2
23616	.157	365.3	.739	.3650	337.9	772.1	83.31	855.4	1193.3
23760	11.225	365.7	2.724	0.3671	338.4	771.7	83.34	855.1	1193.5
23904	.293	366.2	.708	.3692	338.9	771.3	83.37	854.7	1193.6
24048	.361	366.7	.693	.3713	339.4	771.0	83.39	854.3	1193.8
24192	.429	367.2	.678	.3734	339.9	770.6	83.42	854.0	1193.9
24336	.497	367.7	.663	.3754	340.4	770.2	83.45	853.6	1194.1
24480	11.565	368.2	2.649	0.3775	340.9	769.8	83.48	853.3	1194.2
24624	.633	368.6	.634	.3796	341.4	769.4	83.51	852.9	1194.4
24768	.701	369.1	.620	.3817	341.9	769.1	83.54	852.6	1194.5
24912	.769	369.6	.606	.3838	342.4	768.7	83.56	852.2	1194.7
25056	.837	370.0	.592	.3858	342.9	768.3	83.59	851.9	1194.8
25200	11.905	370.5	2.578	0.3879	343.4	767.9	83.62	851.6	1194.9
25344	.973	371.0	.564	.3900	343.9	767.6	83.64	851.2	1195.1
25488	12.041	371.4	.550	.3921	344.3	767.2	83.67	850.9	1195.2
25632	.109	371.9	.537	.3942	344.8	766.8	83.70	850.5	1195.4
25776	.177	372.4	524	.3962	345.3	766.5	83.73	850.2	1195.5
25920	12.245	372.8	2.510	0.3983	345.8	766.1	83.75	849.9	1195.6
26064	.313	373.3	.497	.4004	346.3	765.8	83.77	849.5	1195.8
26208	.381	373.7	.485	.4025	346.7	765.4	83.80	849.2	1195.9
26352	.449	374.2	.472	.4046	347.2	765.0	83.83	848.9	1196.1
26496	.517	374.6	.459	.4066	347.7	764.7	83.86	848.5	1196.2
26640	12.585	375.1	2.447	0.4087	348.1	764.3	83.88	848.2	1196.3
26784	.653	375.5	.434	.4108	348.6	764.0	83.90	847.9	1196.5
26928	.721	376.0	.422	.4129	349.1	763.6	83.92	847.5	1196.6
27072	.789	376.4	.410	.4150	349.5	763.3	83.95	847.2	1196.7
27216	.857	376.8	.398	.4170	350.0	762.9	83.97	846.9	1196.9
27360	12.925	377.3	2.386	0.4191	350.4	762.6	83.99	846.6	1197.0
27504	.993	377.7	.374	.4212	350.9	762.2	84.02	846.3	1197.1
27648	13.061	378.2	.362	.4233	351.3	761.9	84.04	845.9	1197.3
27792	.129	378.6	.351	.4254	351.8	761.6	84.06	845.6	1197.4
27936	.197	379.0	.339	.4275	352.2	761.2	84.08	845.3	1197.5
28080	13.265	379.4	2.328	0.4296	352.7	760.9	84.10	845.0	1197.7
28224	.333	379.9	.317	.4316	353.1	760.5	84.13	844.7	1197.8
28368	.401	380.3	.306	.4337	353.6	760.2	84.16	844.4	1197.9
28512	.469	380.7	.295	.4358	354.0	759.9	84.19	844.0	1198.1
28656	.537	381.1	.284	.4379	354.4	759.5	84.21	843.7	1198.2

TABLE 253 (*continued*).

PROPERTIES OF STEAM.

British Measure.

Pressure in pounds per square inch.	Pressure in pounds per square foot.	Pressure in atmospheres.	Temp. in degrees Fahr.	Volume per pound in cubic feet.	Weight per cubic foot in pounds.	Heat of water per pound in B. T. U.	Internal latent heat per pound of steam in B. T. U.	External latent heat per pound of steam in B. T. U.	Total latent heat per pound of steam in B. T. U.	Total heat per pound of steam in B. T. U.
200	28800	13.605	381.6	2.273	0.4399	354.9	759.2	84.23	843.4	1198.3
201	28944	13.673	382.0	.262	.4420	355.3	758.9	84.26	843.1	1198.4
202	29088	13.742	382.4	.252	.4441	355.8	758.5	84.28	842.8	1198.6
203	29232	13.810	382.8	.241	.4461	356.2	758.2	84.30	842.5	1198.7
204	29376	13.878	383.2	.231	.4482	356.6	757.9	84.33	842.2	1198.8
205	29520	13.946	383.7	2.221	0.4503	357.1	757.5	84.35	841.9	1199.0
206	29664	14.014	384.1	.211	.4523	357.5	757.2	84.37	841.6	1199.1
207	29808	14.082	384.5	.201	.4544	357.9	756.9	84.40	841.3	1199.2
208	29952	14.150	384.9	.191	.4564	358.3	756.6	84.42	841.0	1199.3
209	30096	14.218	385.3	.181	.4585	358.8	756.2	84.44	840.7	1199.4
210	30240	14.286	385.7	2.171	0.4605	359.2	755.9	84.46	840.4	1199.6
211	30384	14.454	386.1	.162	.4626	359.6	755.6	84.48	840.1	1199.7
212	30528	14.522	386.5	.152	.4646	360.0	755.3	84.51	839.8	1199.8
213	30672	14.590	386.9	.143	.4666	360.4	755.0	84.53	839.5	1199.9
214	30816	14.658	387.3	.134	.4687	360.9	754.7	84.55	839.2	1200.1
215	30960	14.726	387.7	2.124	0.4707	361.3	754.3	84.57	838.9	1200.2
216	31104	14.794	388.1	.115	.4727	361.7	754.0	84.60	838.6	1200.3
217	31248	14.862	388.5	.106	.4748	362.1	753.7	84.62	838.3	1200.4
218	31392	14.930	388.9	.097	.4768	362.5	753.4	84.64	838.0	1200.5
219	31536	14.998	389.3	.088	.4788	362.9	753.1	84.66	837.7	1200.7

IO OF THE ELECTROSTATIC TO THE ELECTROMAGNETIC UNIT OF ELECTRICITY = V.

te.	V Cm. per sec.	Mean.	Determined by	Reference.
56		3.11×10^{10}	R. Kohlrausch and W. Weber.	Pogg. Ann. 99; 1856.
68	$2.75–2.92 \times 10^{10}$	2.84	Maxwell.	Phil. Trans.; 1868.
69	2.71–2.88	2.81	Thomson and King.	B. A. Report; 1869.
74	2.86–3.00	2.90	McKichan.	Phil. Mag. 47; 1874.
79	2.950–3.018	2.981	Rowland.	Phil. Mag. 28; 1889.
79	–	2.96	Ayrton and Perry.	Phil. Mag. 7; 1879.
79	–	2.967	Hockin.	B. A. Report; 1879.
80	–	2.955	Shida.	Phil. Mag. 10; 1880.
81	2.98–3.00	2.99	Stoletow.	Jour. de Phys.; 1881.
82	–	2.87	Exner.	Wien. Ber.; 1882.
83	–	2.963	J. J. Thomson.	Phil. Trans.; 1883.
84	3.001–3.029	3.019	Klemenčič.	Wien. Ber. 83, 89, 93; 1881–6.
	3.016–3.031			
86	–	3.015	Colley.	Wied. Ann. 28; 1886.
6–8	2.999–3.009			
	3.003–3.008	3.009	Himstedt.	Wied. Ann. 29, 33, 35; 1887–8.
	3.005–3.015			
88	–	2.92	Thomson, Ayrton and Perry.	Electr. Rev. 23; 1888–9.
89	2.995–3.010	3.000	Rosa.	Phil. Mag. 28; 1889.
90	–	2.996	J. J. Thomson and Searle.	Phil. Trans.; 1890.
91	–	3.009	Pellat.	Jour. de Phys. 10; 1891.
92	2.990–2.995	2.991	Abraham.	Ann. Chim. et Phys. 27; 1829.
96	–	3.001	Hurmuzescu.	Ann. Chim. et Phys. 10; 1897.
98	–	2.9973	Perot and Fabry.	Ann. Chim. et Phys. 13; 1898.
98	–	3.026	Webster.	Phys. Rev. 6; 1898.
99	–	3.009	Lodge and Glazebrook.	Cam. Phil. Soc. 18; 1899.
4–7	2.99706–2.99741	2.9971	Rosa and Dorsey.	Bull. Bur. Standards 3; 1907.

e last of the above determinations is the result of an extended series of measurements upon is forms of condensers, and is believed to be correct within 1/100 per cent. This, however, ies that the International Ohm is 10^9 c.g.s. units. The value of V is therefore subject to alf the error of the International Ohm.

DIELECTRIC STRENGTH.

TABLE 255. — Steady Potential Difference in Volts required to produce a Spark in Air with Ball Electrodes.

Spark length. cm.	$R = 0$. Points.	$R = 0.25$ cm.	$R = 0.5$ cm.	$R = 1$ cm.	$R = 2$ cm.	$R = 3$ cm.	$R = \infty$. Plates.
0.02	–	–	1560	1530			
0.04	–	–	2460	2430	2340		
0.06	–	–	3300	3240	3060		
0.08	–	–	4050	3990	3810		
0.1	3720	5010	4740	4560	4560	4500	4350
0.2	4680	8610	8490	8490	8370	7770	7590
0.3	5310	11140	11460	11340	11190	10560	10650
0.4	5970	14040	14310	14340	14250	13140	13560
0.5	6300	15990	16950	17220	16650	16470	16320
0.6	6840	17130	19740	20070	20070	19380	19110
0.8	8070	18960	23790	24780	25830	26220	24960
1.0	8670	20670	26190	27810	29850	32760	30840
1.5	9960	22770	29970	37260			
2.0	10140	24570	33060	45480			
3.0	11250	28380					
4.0	12210	29580					
5.0	13050						

Based on the results of Baille, Bichat-Blondot, Freyburg, Liebig, Macfarlane, Orgler, Paschen, Quincke, de la Rue, Wolff. For spark lengths from 1 to 200 wave-lengths of sodium light, see Earhart, Phys. Rev. 15, p. 163; Hobbs, Phil. Mag. 10, p. 607, 1905.

TABLE 256. — Alternating Current Potentials required to produce a Spark in Air with various Ball Electrodes.

The potentials given are the maxima of the alternating waves used. Frequency, 33 cycles per second.

Spark length. cm.	$R = 1$ cm.	$R = 1.92$	$R = 5$	$R = 7.5$	$R = 10$	$R = 15$
0.08	3770					
.10	4400	4380	4330	4290	4245	4230
.15	5990	5940	5830	5790	5800	5780
.20	7510	7440	7340	7250	7320	7330
.25	9045	8970	8850	8710	8760	8760
0.30	10480	10400	10270	10130	10180	10150
.35	11980	11890	11670	11570	11610	11590
.40	13360	13300	13100	12930	12980	12970
.45	14770	14700	14400	14290	14330	14320
.50	16140	16070	15890	15640	15690	15690
0.6	18700	18730	18550	18300	18350	18400
.7	21350	21380	21140	20980	20990	21000
.8	23820	24070	23740	23490	23540	23550
0.9	26190	26640	26400	26130	26110	26090
1.0	28380	29170	28950	28770	28680	28610
1.2	32400	34100	33790	33660	33640	33620
1.4	35850	38850	38850	38580	38620	38580
1.6	38750	43400	43570	43250	43520	
1.8	40900	–	48300	47900		
2.0	42950	–	–	52400		

Based upon the results of Kawalski, Phil. Mag. 18, 1909.

DIELECTRIC STRENGTH.

E 257. — Potential Necessary to produce a Spark in Air between more widely Separated Electrodes.

Spark length, cm.	Dull points. Alternating current.	Steady potentials. Ball electrodes. R=1 cm.	Steady potentials. Ball electrodes. R=2.5 cm.	Steady potentials. Cup electrodes. Projection. 4.5 mm.	Steady potentials. Cup electrodes. Projection. 1.5 mm.	Spark length, cm.	Dull points. Alternating current.	Steady potentials. Ball electrodes. R=1 cm.	Steady potentials. Ball electrodes. R=2.5 cm.
3	–	–	–	–	11280	6.0	61000	–	86830
5	–	17610	17620	–	17420	7.0	–	52000	–
7	–	–	23050	–	22950	8.0	67000	52400	90200
.0	12000	30240	31390	31400	31260	10.0	73000	74300	91930
.2	–	33800	36810	–	36700	12.0	82600	–	93300
.5	–	37930	44310	–	44510	14.0	92000	–	94400
.0	29200	42320	56000	56500	56530	15.0	–	–	94700
.5	–	45000	65180	–	68720	16.0	101000	–	101000
.0	40000	46710	71200	80400	81140	20.0	119000		
.5	–	–	75300	–	92400	25.0	140600		
.0	48500	49100	78600	101700	103800	30.0	165700		
.5	–	–	81540	–	114600	35.0	190900		
.0	56500	50310	83800	–	126500				
.5	–	–	–	–	135700				

table for longer spark lengths contains the results of Voege, Ann. der Phys. 14, 1904, using alternating current dull point" electrodes, and the results with steady potential found in the recent very careful work of C. Müller. d. Phys. 29, 1909.

The specially constructed electrodes for the columns headed "cup electrodes" had the form of a projecting knob 3 cm. in diameter and having a height of 4.5 mm. and 1.5 mm. respectively, attached to the plane face of the electrodes. These electrodes give a very satisfactory linear relation between the spark lengths and the voltage throughout the range studied.

TABLE 258. — Effect of the Pressure of the Gas on the Dielectric Strength.

Voltages are given for different spark lengths *l*.

Pressure. cm. Hg.	*l*=0.04	*l*=0.06	*l*=0.08	*l*=0.10	*l*=0.20	*l*=0 30	*l*=0.40	*l*=0.50
2	–	–	–	–	744	939	1110	1266
4	–	483	567	648	1015	1350	1645	1915
6	–	582	690	795	1290	1740	2140	2505
10	–	771	933	1090	1840	2450	3015	3580
15	–	1060	1280	1490	2460	3300	4080	4850
25	1110	1420	1725	2040	3500	4800	6000	7120
35	1375	1820	2220	2615	4505	6270	7870	9340
45	1640	2150	2660	3120	5475	7650	9620	11420
55	1820	2420	3025	3610	6375	8950	11290	13455
65	2040	2720	3400	4060	7245	10210	12950	15470
75	2255	3035	3805	4565	8200	11570	14650	17450

table is based upon the results of Orgler, 1899. See this paper for work on other gases (or Landolt-Börnstein-hoffer).
long spark lengths in various gases see Voege, Electrotechn. Z. 28, 1907. For dielectric strength of air and CO_2 ndrical air condensers, see Wien, Ann. d. Phys. 29, 1909.

DIELECTRIC STRENGTH.

TABLE 259. — Dielectric Strength of Materials.

Potential necessary for puncture expressed in kilovolts per centimetre thickness of the dielec

Substance.	Kilovolts per cm.	Substance.	Kilovolts per cm.	Substance.	Kilovo per c
Ebonite	300–1100	Oils: Thickness.		Papers:	
Empire cloth	80–300	Castor 0.2 mm.	190	Beeswaxed	77
" paper	450	" 1.0 "	130	Blotting	15
Fibre	20	Cottonseed	70	Manilla	2
Fuller board	200–300	Lard 0.2 "	140	Paraffined	50
Glass	300–1500	" 1.0 "	40	Varnished	100–
Granite (fused)	90	Linseed, raw 0.2 "	185	Paraffine:	
Guttapercha	80–200	" " 1.0 "	90	Melted	7
Impregnated jute	20	" boiled 0.2 "	190	Melt point.	
Leatheroid	30–60	" " 1.0 "	80	Solid 43°	35
Linen, varnished	100–200	Lubricating	50	" 47°	40
Liquid air	40–90	Neatsfoot 0.2 "	200	" 52°	23
Mica: Thickness.		" 1.0 "	90	" 70°	45
Madras 0.1 mm.	1600	Olive 0.2 "	170	Presspaper	45–
" 1.0 "	300	" 1.0 "	75	Rubber	160–
Bengal 0.1 "	2200	Paraffin 0.2 "	215	Vaseline	90–
" 1.0 "	700	" 1.0 "	160	Thickness.	
Canada 0.1 "	1500	Sperm, mineral 0.2 "	180	Xylol 0.2 mm.	14
" 1.0 "	500	" " 1.0 "	85	" 1.0 "	8
South America	1500	" natural 0.2 "	195		
Micanite	4000	" " 1.0 "	90		
		Turpentine 0.2 "	160		
		" 1.0 "	110		

TABLE 260. — Potentials in Volts to Produce a Spark in Kerosene.

Spark length. mm.	Electrodes Balls of Diam. *d*.			
	0.5 cm.	1 cm.	2 cm.	3 cm.
0.1	3800	3400	2750	2200
.2	7500	6450	4800	3500
.3	10250	9450	7450	4600
.4	11750	10750	9100	5600
.5	13050	12400	11000	6900
.6	14000	13550	12250	8250
.8	15500	15100	13850	10450
1.0	16750	16400	15250	12350

Determinations of the dielectric strength of the same substance by different observers do not agree well. For cussion of the sources of error see Mościcki, Electrotechn. Z. 25, 1904.

For more detailed information on the dependence of the sparking distance in oils as a function of the nature electrodes, see Edmondson, Phys. Review 6, 1898.

UTE MEASUREMENTS OF CURRENT AND OF THE ELECTROMOTIVE FORCE OF STANDARD CELLS.

Observer.	Method.	Electromotive Force of		Electrochemical Equivalent found with Voltameter of	
		Clark Cell at 15°.	Weston Cell at 20°.	Rayleigh Form.	Porous Cup Form.
		volts.	volts.	mg.	mg.
F. and W. Kohlrausch	Tangent galvanometer . Filter paper voltameter	–	–	1.1183	
Rayleigh & Sidgwick .	Current balance . . . Filter paper voltameter	1.4345	–	1.1179	
Potier and Pellat . .	Current balance . . . Filter paper voltameter	–	–	1.1192	
Kahle	Current balance . . .	1.4328	1.0186	1.1182	
Patterson and Guthe .	Electrodynamometer . Silver oxide voltameter	–	–	–	1.1192
Carhart and Guthe . .	Electrodynamometer .	1.4333			
Pellat and Leduc . .	Current balance . . . Leduc voltameter . .	–	–	1.1195	
Van Dijk and Kunst .	Tangent galvanometer . Filter paper voltameter	–	–	1.1182	
Guthe	Electrodynamometer .	1.4330	1.0185	–	1.1177
Ayrton, Mather and Smith	Current balance . . .	1.4323	1.01819		
Smith and Lowry . .	Filter paper voltameter	–	–	1.11827	
Janet, Laporte and Jouaust	Filter paper voltameter Current balance . . .	–	1.0187	1.1182	
Pellat	Current balance . . .	–	1.0184		
Guillet	Current balance . . .	–	1.0182		

ost probable value of the Weston cell at 20° is 1.0182 volts, assuming the International e 10^9 c. g. s. units and the volt to be 10^8 c. g. s. units. The corresponding value of the ll, as prepared at present, at 15°, is 1.4324 volts.

gal values of the Weston cell, however, are different in different countries, as follows:

ed States (Bureau of Standards) . . . . . 1.019125* v. at 20°
nany (Physikalisch-Technische Reichsanstalt) . . . . . 1.0186 volts at 20°
land (National Physical Laboratory) . . . . . 1.0184 volts at 20°

lue of the Weston standard cell, used in the United States, is based upon the value by the Chicago Electrical Congress (1893) for the Clark cell. The value used by Ger- s adopted in 1896, and is based on Kahle's work at the Reichsanstalt. The value used nd was adopted January 1, 1909, and is based on the recommendation of the London l Conference of 1908. It is expected that a new value will soon be agreed upon by the onal Committee on Electrical Units and Standards, which will be adopted generally in all

lue of the electrochemical equivalent of silver is different when filter paper (Rayleigh k, or other textile is used to separate the anode from the cathode from what it is when a up is employed. The value found is also affected by the addition of silver oxide to the rate solution. The legal value in all countries is 1.118 mg. of silver per coulomb, and this the value found when using a porous cup voltameter, and the best determinations of the hat have been made by absolute current balances. Some corrections have been made to es given in the above table for the excess due to filter paper, but such corrections are very i.

* Based on 1.0189 at 25° C.

COMPOSITION AND ELECTROMOTIVE FORCE OF VOLTAIC CELLS.

The electromotive forces given in this table approximately represent what may be expected from a cell in good working order, but with the exception of the standard cells all of them are subject to considerable variation.

(a) DOUBLE FLUID CELLS.

Name of cell.	Negative pole.	Solution.	Positive pole.	Solution.	E.M.F. in volts.
Bunsen . .	Amalgamated zinc	1 part H_2SO_4 to 12 parts H_2O .	Carbon	Fuming H_2NO_3 .	1.94
" . .	" "	"	"	HNO_3, density 1.38	1.86
Chromate .	" "	12 parts $K_2Cr_2O_7$ to 25 parts of H_2SO_4 and 100 parts H_2O . .	"	1 part H_2SO_4 to 12 parts H_2O .	2.00
" .	" "	1 part H_2SO_4 to 12 parts H_2O .	"	12 parts $K_2Cr_2O_7$ to 100 parts H_2O	2.03
Daniell* .	" "	1 part H_2SO_4 to 4 parts H_2O .	Copper	Saturated solution of $CuSO_4+5H_2O$	1.06
" .	" "	1 part H_2SO_4 to 12 parts H_2O .	"	"	1.09
" .	" "	5% solution of $ZnSO_4+6H_2O$	"	"	1.08
" .	" "	1 part NaCl to 4 parts H_2O .	"	"	1.05
Grove . .	" "	1 part H_2SO_4 to 12 parts H_2O .	Platinum	Fuming HNO_3 . .	1.93
" . .	" "	Solution of $ZnSO_4$	"	HNO_3, density 1.33	1.66
" . .	" "	H_2SO_4 solution, density 1.136 .	"	Concentrated HNO_3	1.93
" . .	" "	H_2SO_4 solution, density 1.136 .	"	HNO_3, density 1.33	1.79
" . .	" "	H_2SO_4 solution, density 1.06 .	"	"	1.71
" . .	" "	H_2SO_4 solution, density 1.14 .	"	HNO_3, density 1.19	1.66
" . .	" "	H_2SO_4 solution, density 1.06 .	"	" " "	1.61
" . .	" "	NaCl solution . .	"	" density 1.33	1.88
Marié Davy	" "	1 part H_2SO_4 to 12 parts H_2O	Carbon	Paste of protosulphate of mercury and water . . .	1.50
Partz . .	" "	Solution of $MgSO_4$	"	Solution of $K_2Cr_2O_7$	2.06

* The Minotto or Sawdust, the Meidinger, the Callaud, and the Lockwood cells are modifications of the Daniell and hence have about the same electromotive force.

COMPOSITION AND ELECTROMOTIVE FORCE OF VOLTAIC CELLS.

Name of cell.	Negative pole.	Solution.	Positive pole.	E. M. F. in volts.
(b) SINGLE FLUID CELLS.				
Leclanche . . .	Amal. zinc	Solution of sal-ammoniac	Carbon. Depolarizer: manganese peroxide with powdered carbon	1.46
Chaperon . . .	" "	Solution of caustic potash	Copper. Depolarizer: CuO . . .	0.98
Edison-Lelande .	" "	"	"	0.70
Chloride of silver	Zinc . .	23 % solution of sal-ammoniac	Silver. Depolarizer: silver chl'ride	1.02
Law	" . .	15 % " "	Carbon	1.37
Dry cell (Gassner)	" . .	1 pt. ZnO, 1 pt. NH_4Cl, 3 pts. plaster of paris, 2 pts. $ZnCl_2$, and water to make a paste . .	"	1.3
Poggendorff . .	Amal. zinc	Solution of chromate of potash	"	1.08
" . . .	" "	12 parts $K_2Cr_2O_7$ + 25 parts H_2SO_4 + 100 parts H_2O . .	"	2.01
J. Regnault . . .	" "	1 part H_2SO_4 + 12 parts H_2O + 1 part $CaSO_4$ . .	Cadmium . . .	0.34
Volta couple . .	Zinc . .	H_2O	Copper	0.98
(c) STANDARD CELLS.				
Weston normal .	Cadmi'm am'lgam	Saturated solution of $CdSO_4$	Mercury. Depolarizer: paste of Hg_2SO_4 and $CdSO_4$	1.0191 at 20° C
Clark standard .	Zinc am'lgam	Saturated solution of $ZnSO_4$	Mercury. Depolarizer: paste of Hg_2SO_4 and $ZnSO_4$	1.434* at 15° C
(d) SECONDARY CELLS.				
Lead accumulator	Lead . .	H_2SO_4 solution of density 1.1 . . .	PbO_2	2.2†
Regnier (1) . . .	Copper .	$CuSO_4 + H_2SO_4$ . .	"	1.68 to 0.85, average 1.3.
" (2) . . .	Amal. zinc	$ZnSO_4$ solution . . .	" in H_2SO_4 .	2.36
Main	Amal. zinc	H_2SO_4 density ab't 1.1	"	2.50
Edison	Iron . .	KOH 20 % solution .	A nickel oxide .	1.1, mean of full discharge.

* E. M. F. hitherto used at Bureau of Standards. See p. 251. The temperature formula is $E_t = E_{20} - 0.000406 (t-20) - 0.00000095 (t-20)^2 + 0.00000001 (t-20)^3$. The value given is that adopted by the Chicago International Electrical Congress in 1893. The temperature formula is $E_t = E_{15} - 0.00119 (t-15) - 0.000007 (t-15)^2$.

† F. Streintz gives the following value of the temperature variation $\frac{dE}{dt}$ at different stages of charge:

E. M. F.	1.9223	1.9828	2.0031	2.0084	2.0105	2.0779	2.2070
$dE/dt \times 10^6$	140	228	335	285	255	130	73

Dolezalek gives the following relation between E. M. F. and acid concentration:

Per cent H_2SO_4	64.5	52.2	35.3	21.4	5.2
E.M.F., 0° C	2.37	2.25	2.10	2.00	1.89

CONTACT DIFFERENCE

Solids with Liqui

Temperature of sol

	Carbon.	Copper.	Iron.	Lead.	Platinum.	Tin.	Zinc
Distilled water	.01 to .17	.269 to .100	.148	.171	.285 to .345	.177	— to +
Alum solution: saturated at 16°.5 C.	–	—.127	—.653	—.139	.246	—.225	—
Copper sulphate solution: sp. gr. 1.087 at 16°.6 C.	–	.103	–	–	–	–	
Copper sulphate solution: saturated at 15° C.	–	.070	–	–	–	–	
Sea salt solution: sp. gr. 1.18 at 20°.5 C.	–	—.475	—.605	–	—.856	—.334	—
Sal-ammoniac solution: saturated at 15°.5 C.	–	—.396	—.652	—.189	.059	—.364	—
Zinc sulphate solution: sp. gr. 1.125 at 16°.9 C.	–	–	–	–	–	–	—
Zinc sulphate solution: saturated at 15°.3 C.	–	–	–	–	–	–	—
One part distilled water + 3 parts saturated zinc sulphate solution	–	–	–	–	–	–	—
Strong sulphuric acid in distilled water:							
1 to 20 by weight	–	–	–	–	–	–	—
1 to 10 by volume	about —.035	–	–	–	–	–	
1 to 5 by weight	–	–	–	–	–	–	
5 to 1 by weight	.01 to 3.0	–	–	—.120	–	—.25	
Concentrated sulphuric acid	.55 to .85	1.113	–	.72 to 1.252	1.3 to 1.6	–	
Concentrated nitric acid	–	–	–	–	.672	–	
Mercurous sulphate paste	–	–	–	–	–	–	
Distilled water containing trace of sulphuric acid	–	–	–	–	–	–	—

* Everett's "Units and Physical Constants:"

POTENTIAL IN VOLTS.

Liquids with Liquids in Air.*

during experiment about 16° C.

	Amalgamated zinc.	Brass.	Mercury.	Distilled water.	Alum solution: saturated at 16°.5 C.	Copper sulphate solution: saturated at 15° C.	Zinc sulphate solution: sp. gr. 1.25 at 16°.9 C.	Zinc sulphate solution: saturated at 15°.3 C.	One part distilled water + 3 pts. zinc sulphate.	Strong nitric acid.
Distilled water	.100	.231	–	–	–	—.043	–	.164	–	–
Alum solution: saturated at 16°.5 C.	–	—.014	–	–	–	–	–	–	–	–
Copper sulphate solution: sp. gr. 1.087 at 16°.6 C.	–	–	–	–	–	–	.090	–	–	–
Copper sulphate solution: saturated at 15° C. . .	–	–	–	—.043	–	–	–	.095	.102	–
Sea salt solution: sp. gr. 1.18 at 20°.5 C. . . .	–	—.435	–	–	–	–	–	–	–	–
Sal-ammoniac solution: saturated at 15°.5 C. .	–	—.348	–	–	–	–	–	–	–	–
Zinc sulphate solution: sp. gr. 1.125 at 16°.9 C.	–	–	–	–	–	–	–	–	–	–
Zinc sulphate solution: saturated at 15°.3 C. .	—.284	–	–	—.200	–	—.095	–	–	–	–
One part distilled water + 3 parts saturated zinc sulphate solution . .	–	–	–	–	–	—.102	–	–	–	–
Strong sulphuric acid in distilled water:										
1 to 20 by weight . . .	–	–	–	–	–	–	–	–	–	–
1 to 10 by volume . . .	—.358	–	–	–	–	–	–	–	–	–
1 to 5 by weight	.429	–	–	–	–	–	–	–	–	–
5 to 1 by weight	–	—.016	–	–	–	–	–	–	–	–
Concentrated sulphuric acid	.848	–	–	1.298	1.456	1.269	–	1.699	–	–
Concentrated nitric acid .			–	–	–	–	–	–	–	–
Mercurous sulphate paste .	–	–	.475	–	–	–	–	–	–	–
Distilled water containing trace of sulphuric acid .	–	–	–	–	–	–	–	–	–	.078

Ayrton and Perry's results, prepared by Ayrton.

TABLE 264.

CONTACT DIFFERENCE OF POTENTIAL IN VOLTS.

Solids with Solids in Air.*

The following results are the "Volta differences of potential," as measured by an electrom
They represent the difference of the potentials of the air near each of two metals placed in
tact. This should not be confused with the junction electromotive force at the junction of
metals in metallic contact, which has a definite value, proportional to the coefficient of Pe
effect. The Volta difference of potential has been found to vary with the condition of the
tallic surfaces and with the nature of the surrounding gas. No great reliance, therefore, ca
placed on the tabulated values.
The temperature of the substances during the experiment was about 18° C.

	Carbon.	Copper.	Iron.	Lead.	Platinum.	Tin.	Zinc.	Zinc amalgam.	Bra
Carbon . . .	0	.370	.485	.858	.113	.795	1.096†	1.208†	.4
Copper . . .	—.370	0	.146	.542	—.238	.456	.750	.894	.0
Iron	—.485†	—.146	0	.401†	—.369	.313†	.600†	.744†	—.0
Lead . . .	—.858	—.542	—.401	0	—.771	—.099	.210	.357†	—.4
Platinum . .	—.113†	.238	.369	.771	0	.690	.981	1.125†	.2
Tin	—.795†	—.458	—.313	.099	—.690	0	.281	.463	—.3
Zinc	—1.096†	—.750	—.600	—.216	—.981	.281	0	.144	—.6
" amalgam	—1.208†	—.894	—.744	—.357†	—1.125†	—.463	—.144	0	—.8
Brass . . .	—.414	—.087	.064	.472	—.287	.372	.679	.822	

The numbers not marked were obtained by direct experiment, those marked with a da
ger by calculation, on the assumption that in a compound circuit of metals, all at the sa
temperature, there is no electromotive force.

The numbers in the same vertical column are the differences of potential in volts betwe
the substance named at the top of the column and the substance named on the same line
the first column, when the two substances are in contact.

The metals used were those ordinarily obtained in commerce.

* Everett's "Units and Physical Constants." The table is from Ayrton and Perry's experiments, and wa
pared by Ayrton.

DIFFERENCE OF POTENTIAL BETWEEN METALS IN SOLUTIONS OF SALTS.

The following numbers are given by G. Magnanini* for the difference of potential in hundredths of a volt between zinc in a normal solution of sulphuric acid and the metals named at the head of the different columns when placed in the solution named in the first column. The solutions were contained in a U-tube, and the sign of the difference of potential is such that the current will flow from the more positive to the less positive through the external circuit.

Strength of the solution in gramme molecules per litre.		Zinc.†	Cadmium.†	Lead.	Tin.	Copper.	Silver.
No. of molecules.	Salt.	Difference of potential in centivolts.					
0.5	H_2SO_4	0.0	36.6	51.3	51.3	100.7	121.3
1.0	NaOH	—32.1	19.5	31.8	0.2	80.2	95.8
1.0	KOH	—42.5	15.5	32.0	—1.2	77.0	104.0
0.5	Na_2SO_4	1.4	35.6	50.8	51.4	101.3	120.9
1.0	$Na_2S_2O_3$	—5.9	24.1	45.3	45.7	38.8	64.8
1.0	KNO_3	11.8‡	31.9	42.6	31.1	81.2	105.7
1.0	$NaNO_3$	11.5	32.3	51.0	40.9	95.7	114.8
0.5	K_2CrO_4	23.9‡	42.8	41.2	40.9	94.6	121.0
0.5	$K_2Cr_2O_7$	72.8	61.1	78.4	68.1	123.6	132.4
0.5	K_2SO_4	1.8	34.7	51.0	40.9	95.7	114.8
0.5	$(NH_4)_2SO_4$	—0.5	37.1	53.2	57.6‡	101.5	125.7
0.25	$K_4FeC_6N_6$	—6.1	33.6	50.7	41.2	—‡	87.8
0.167	$K_6Fe_2(CN)_2$	41.0§	80.8	81.2	130.9	110.7	124.9
1.0	KCNS	—1.2	32.5	52.8	52.7	52.5	72.5
1.0	$NaNO_3$	4.5	35.2	50.2	49.0	103.6	104.6?
0.5	$SrNO_3$	14.8	38.3	50.6	48.7	103.0	119.3
0.125	$Ba(NO_3)_2$	21.9	39.3	51.7	52.8	109.6	121.5
1.0	KNO_3	—‡	35.6	47.5	49.9	104.8	115.0
0.2	$KClO_3$	15–10‡	39.9	53.8	57.7	105.3	120.9
0.167	$KBrO_3$	13–20‡	40.7	51.3	50.9	111.3	120.8
1.0	NH_4Cl	2.9	32.4	51.3	50.9	81.2	101.7
1.0	KF	2.8	22.5	41.1	50.8	61.3	61.5
1.0	NaCl	—	31.9	51.2	50.3	80.9	101.3
1.0	KBr	2.3	31.7	47.2	52.5	73.6	82.4
1.0	KCl	—	32.1	51.6	52.6	81.6	107.6
0.5	Na_2SO_3	—8.2	28.7	41.0	31.0	68.7	103.7
‖	NaOBr	18.4	41.6	73.1	70.6‡	89.9	99.7
1.0	$C_4H_6O_6$	5.5	39.7	61.3	54.4§	104.6	123.4
0.5	$C_4H_6O_6$	4.1	41.3	61.6	57.6	110.9	125.7
0.5	$C_4H_4KNaO_6$	—7.9	31.5	51.5	42–47	100.8	119.7

* "Rend. della R. Acc. di Roma," 1890.

† Amalgamated.

‡ Not constant.

§ After some time.

‖ A quantity of bromine was used corresponding to NaOH = 1.

THERMOELECTRIC POWER.

The thermoelectric power of a circuit of two metals is the electromotive force produced by one degree C. difference of temperature between the junctions. The thermoelectric power varies with the temperature, thus: thermoelectric power $= Q = dE/dt = A + Bt$, where A is the thermoelectric power at 0° C., B is a constant, and t is the mean temperature of the junctions. The neutral point is the temperature at which $dE/dt = 0$, and its value is $-A/B$. When a current is caused to flow in a circuit of two metals originally at a uniform temperature, heat is liberated at one of the junctions and absorbed at the other. The rate of production or liberation of heat at each junction, or Peltier effect, is given in calories per second, by multiplying the current by the coefficient of the Peltier effect. This coefficient in calories per coulomb $= QT/\mathcal{J}$, in which Q is in volts, T is the absolute temperature of the junction, and $\mathcal{J} = 4.19$. Heat is also liberated or absorbed in each of the metals as the current flows through portions of varying temperature. The rate of production or liberation of heat in each metal, or the Thomson effect, is given in calories per second by multiplying the current by the coefficient of the Thomson effect. This coefficient in calories per coulomb, $= BT\theta/\mathcal{J}$, in which B is in volts per degree C., T is the mean absolute temperature of the junctions, and θ is the difference of temperature of the junctions. (BT) is Sir W. Thomson's "Specific Heat of electricity." The algebraic signs are so chosen in the following table that when A is positive, the current flows in the metal considered from the cold junction to the hot. When B is positive, Q increases (algebraically) with the temperature. The values of A, B, and thermoelectric power, in the following table are with respect to lead as the other metal of the thermoelectric circuit. The thermoelectric power of a couple composed of two metals, 1 and 2, is given by subtracting the value for 2 from that for 1; when this difference is positive, the current flows from the cold junction to the hot in 1. In the following table, A is given in microvolts, B in microvolts per degree C., and the neutral point in degrees C.

The table has been compiled from the results of Becquerel, Matthiessen and Tait; in reducing the results, the electromotive force of the Grove and Daniell cells has been taken as 1.95 and 1.07 volts. The value for constantin was reduced from results given in Landolt-Börnstein's tables. The thermoelectric powers of antimony and bismuth alloys are given by Becquerel in the reference given below.

Substance.	A Microvolts.	B Microvolts.	Thermoelectric power at mean temp. of junctions (microvolts).		Neutral point $-\frac{A}{B}$	Authority.
			20° C.	50° C.		
Aluminum	0.76	—0.0039	0.68	0.56	195	T
Antimony, comm'l pressed wire	–	–	—6.0	–	–	M
" axial	–	–	—22.6	–	–	"
" equatorial	–	–	—26.4	–	–	"
" ordinary	–	–	—17.0	–	–	B
Argentan	11.94	0.0506	12.95	14.47	—236	T
"	–	–	–	12.7	–	B
Arsenic	–	–	13.56	–	–	M
Bismuth, comm'l pressed wire	–	–	97.0	–	–	"
" pure " "	–	–	89.0	–	–	"
" crystal, axial	–	–	65.0	–	–	"
" " equatorial	–	–	45.0	–	–	"
" commercial	–	–	–	39.9	–	B
Cadmium	—2.63	—0.0424	—3.48	—4.75	—62	T
" fused	–	–	–	—2.45	–	B
Cobalt	–	–	22.	–	–	M
Constantin	–	–	–	+19.3	–	–
Copper	—1.34	—0.0094	—1.52	—1.81	—143	T
" commercial	–	–	—0.10	–	–	M
" galvanoplastic	–	–	—3.8	–	–	"
Gold	–	–	—1.2	–	–	"
"	—2.80	—0.0101	—3.0	—3.30	[—277]	T
Iron	—17.15	0.0482	—16.2	—14.74	356	"
" pianoforte wire	–	–	—17.5	–	–	M
" commercial	–	–	–	—12.10	–	B
" "	–	–	–	—9.10	–	"
Lead	–	0.0000	0.00	0.00	–	–
Magnesium	—2.22	0.0094	—2.03	—1.75	236	T
Mercury	–	–	0.413	–	–	M
"	–	–	–	3.30	–	B
Nickel	–	–	–	15.50	–	"
" (—18° to 175°)	21.8	0.0506	22.8	24.33	[—431]	T
" (250°–300°)	83.57	—0.2384	–	–	–	"
" (above 340°)	3.04	0.0506	–	–	–	"

THERMOELECTRIC POWER.

TABLE 266.—Thermoelectric Power (*continued*).

Substance.	*A* Microvolts.	*B* Microvolts.	Thermoelectric power at mean temp. of junctions (microvolts).		Neutral point $-\frac{A}{B}$.	Authority.
			20° C.	50° C.		
Palladium	6.18	0.0355	6.9	7.96	—174	T
"	–	–	–	6.9	–	B
Phosphorus (red)	–	–	—29.9	–	–	M
Platinum	–	–	—0.9	–	–	"
" (hardened)	—2.57	0.0074	—2.42	—2.20	347	T
" (malleable)	0.60	0.0109	8.82	1.15	—55	"
" wire	–	–	–	—0.94	–	B
" another specimen	–	–	–	2.14	–	"
Platinum-iridium alloys:						
85% Pt+15% Ir	—7.90	—0.0062	—8.03	—8.21	[—1274]	T
90% Pt+10% Ir	—5.90	0.0133	—5.63	—5.23	444	"
95% Pt+5% Ir	—6.15	—0.0055	—6.26	—6.42	[—1118]	"
Selenium	–	–	—807.	–	–	M
Silver	—2.12	—0.0147	—2.41	—2.86	—144	T
" (pure hard)	–	–	—3.00	–	–	M
" wire	–	–	–	—2.18	–	B
Steel	—11.27	0.0325	—10.62	—9.65	347	T
Tellurium	–	–	—502.	–	–	M
"	–	–	–	—429.3	–	B
Tin (commercial)	–	–	–	—0.33	–	"
"	–	–	—0.1	–	–	M
"	0.43	—0.0055	0.33	0.16	78	T
Zinc	—2.32	—0.0238	—2.79	—3.51	—98	"
" pure pressed	–	–	—3.7	–	–	M

B Ed. Becquerel, "Ann. de Chim. et de Phys." [4] vol. 8.
M Matthiesen, "Pogg. Ann." vol. 103, reduced by Fleming Jenkin.
T Tait, "Trans. R. S. E." vol. 27, reduced by Mascart.

TABLE 267.—Thermoelectric Power against Platinum.

One junction is supposed to be at 0° C; + indicates that the current flows from the 0° junction into the platinum. The rhodium and iridium were rolled, the other metals drawn.*

Temperature, °C.	Au.	Ag.	90%Pt+10%Pd.	10%Pt+90%Pd.	Pd.	90%Pt+10%Rh.	90%Pt+10%Ru.	Ir.	Rh.
—185	—0.15	—0.16	—0.11	+0.24	+0.77	–	—0.53	—0.28	—0.24
—80	—0.31	—0.30	—0.09	+0.15	+0.39	–	—0.39	—0.32	—0.31
+100	+0.74	+0.72	+0.26	—0.19	—0.56	–	+0.73	+0.65	+0.65
+200	+1.8	+1.7	+0.62	—0.31	—1.20	–	+1.6	+1.5	+1.5
+300	+3.0	+3.0	+1.0	—0.37	—2.0	+2.3	+2.6	+2.5	+2.6
+400	+4.5	+4.5	+1.5	—0.35	—2.8	+3.2	+3.6	+3.6	+3.7
+500	+6.1	+6.2	+1.9	—0.18	—3.8	+4.1	+4.6	+4.8	+5.1
+600	+7.9	+8.2	+2.4	+0.12	—4.9	+5.1	+5.7	+6.1	+6.5
+700	+9.9	+10.6	+2.9	+0.61	—6.3	+6.2	+6.9	+7.6	+8.1
+800	+12.0	+13.2	+3.4	+1.2	—7.9	+7.2	+8.0	+9.1	+9.9
+900	+14.3	+16.0	+3.8	+2.1	—9.6	+8.3	+9.2	+10.8	+11.7
+1000	+16.8	–	+4.3	+3.1	—11.5	+9.5	+10.4	+12.6	+13.7
+1100	–	–	+4.8	+4.2	—13.5	+10.6	+11.6	+14.5	+15.8
+(1300)	–	–	–	–	–	+13.1	+14.2	+18.6	+20.4
+(1500)	–	–	–	–	–	+15.6	+16.9	+23.1	+25.6

* Holborn and Day.

PELTIER EFFECT.

The coefficient of Peltier effect may be calculated from the constants *A* and *B* of Table 255, as there shown. Experimental results, expressed in slightly different units, are here given. The figures are for the heat production at a junction of copper and the metal named, in calories per ampere-hour. The current flowing from copper to the metal named, a positive sign indicates a warming of the junction. The temperature not being stated by either author, and Le Roux not giving the algebraic signs, these results are not of great value.

Metals.	Calories per ampere-hour.	
	Jahn.*	Le Roux.†
Antimony (Becquerel's)‡	-	13.02
" (commercial)	-	4.8
Bismuth (pure)	-	19.1
" (Becquerel's)§	-	25.8
Cadmium . . .	—0.616	0.46
German silver . . .	-	2.47
Iron	—3.613	2.5
Nickel	4.362	
Platinum	0.320	
Silver	—0.413	
Zinc	—0.585	0.39

* "Wied. Ann." vol. 34, p. 767.
† "Ann. de Chim. et de Phys." (4) vol. 10, p. 201.
‡ Becquerel's antimony is 806 parts Sb+406 parts Zn+121 parts Bi.
§ Becquerel's bismuth is 10 parts Bi+1 part Sb.

RIOUS DETERMINATIONS OF THE VALUE OF THE OHM.

Observer.	Method.	Value of B. A. unit in ohms.	Value of Siemens unit, B. A. unit.	Value of ohm in cms. of Hg.
rd Rayleigh .	Rotating coil . .	0.98651	0.95412	106.24
rd Rayleigh .	Lorenz method . .	.98677	.95412	106.21
ascart . . .	Induced current . .	.98611	.95374	106.33
wland . . .	Mean of several methods	.98644	.95349	106.32
hlrausch . .	Damping of magnets .	.98660	.95338	106.32
azebrook . .	Induced currents . .	.98665	.95352	106.29
uilleumeier . .	Mean effect of induced currents . . .	.98686	.95355	106.31
ncan and Wilkes	Lorenz method . .	.98634	.95341	106.34
nes . . .	Lorenz method . .	–	–	106.31
nes . . .	Lorenz method . .	–	–	106.33
mstedt . .	Mean effect of induced current . . .	–	–	106.28
rton and Jones .	Lorenz method . .	(.98634)	–	106.27
illet . . .	Mean effect of induced current, using a calibrated 1000-ohm coil . . .		–	106.20
	Means . . .	0.98651	0.95366	106.288
ld . . .	Damping of magnet .	–	–	106.03
edemann . .	Earth inductor . .	–	–	106.19
F. Weber . .	Induced current . .	–	–	105.37
F. Weber . .	Rotating coil . . .	–	–	106.16
iti . . .	Mean effect of induced current, using German silver coils certified by makers		–	105.89
mstedt . .	Mean effect of induced current, using German silver coils certified by makers		–	105.98
renz . . .	Lorenz method . .	–	–	105.93
rn . . .	Damping of magnet .	–	–	106.24

alue of the ohm is the resistance of a column of mercury of uniform cross-section, 521 gms., and having a length of 106.30 cms. This is known as the international ry ohms conforming to these specifications have been prepared in recent years at sch-Technische Reichsanstalt and the National Physical Laboratory, and are now at the Bureau of Standards. The wire standards of resistance at the above-named gree in value to within two parts in 100000. Hence there is a very close agreement of precision resistances calibrated at these laboratories.

SPECIFIC RESISTANCE OF METALLIC WIRES.

This table is modified from the table compiled by Jenkin (1862) from Matthiessen's results by taking the resistance of silver, gold, and copper from the observed metre gramme value and assuming the densities found by Matthiessen, namely, 10.468, 19.265, and 8.95.

Substance.	Resistance at 0° C. of a wire one cm. long, one sq. cm. in section.	Resistance at 0° C. of a wire one metre long, one mm. in diam.	Resistance at 0° C. of a wire one metre long, weighing one gramme.	Resistance at 0° C. of a wire one foot long, 1/60 in. in diam.	Resistance at 0° C. of a wire one foot long, weighing one grain.	Percentage increase of resistance for 1° C. increase of temp. at 20° C.
Silver annealed	1.460 × 10^{-6}	0.01859	.1523	8.781	.2184	0.377
" hard drawn	1.585 "	0.02019	.1659	9.538	.2379	-
Copper annealed	1.584 "	0.02017	.1421	9.529	.2037	0.388
" hard drawn	1.619 "	0.02062	.1449	9.741	.2078	-
Gold annealed	2.088 "	0.02659	.4025	12.56	.5771	0.365
" hard drawn	2.125 "	0.02706	.4094	12.78	.5870	-
Aluminium annealed	2.906 "	0.03699	.0747	17.48	.1071	-
Zinc pressed	5.613 "	0.07146	.4012	33.76	.5753	0.365
Platinum annealed	9.035 "	0.1150	1.934	54.35	2.772	-
Iron "	9.693 "	0.1234	.7551	58.31	1.083	-
Nickel "	12.43 "	0.1583	1.057	74.78	1.515	-
Tin pressed	13.18 "	0.1678	.9608	79.29	1.377	0.365
Lead "	19.14 "	0.2437	2.227	115.1	3.193	0.387
Antimony pressed	35.42 "	0.4510	2.379	213.1	3.410	0.389
Bismuth "	130.9 "	1.667	12.86	787.5	18.43	0.354
Mercury "	94.07 "	1.198	12.79	565.9	18.34	0.072
Platinum-silver, 2 parts Ag, 1 part Pt, by weight	24.33 "	0.3098	2.919	146.4	4.186	0.031
German silver	20.89 "	0.2660	1.825	125.7	2.617	0.044
Gold-silver, 2 parts Au, 1 part Ag, by weight	10.84 "	0.1380	1.646	65.21	2.359	0.065

SPECIFIC RESISTANCE OF METALS.

The specific resistance is here given as the resistance, in microhms, per centimetre of a bar one square centimetre in cross section.

Substance.	Physical state.	Specific resistance.	Temp. ° C.	Authority.
Aluminum	–	2.6–3.0	0	Various.
Antimony	–	35.4–45.8	0	"
"	Solid	182.8	Melting-point	De la Rive.
"	Liquid	129.2	"	"
"	–	137.7	860	"
Arsenic	–	33.3	0	Matthiessen and Vogt.
Bismuth	Electrolytic soft	108.0	0	Van Aubel.
"	" hard	108.7	0	"
"	Commercial	110–268	0	Various.
Boron	Pulverized and compressed	8×10^{10}	–	Moissan.
Cadmium	–	6.2–7.0	–	Various.
"	Solid	16.5	318	Vassura.
"	Liquid	37.9	318	"
Gold	–	2.04–2.09	0	Various.
Calcium	–	7.5	16.8	Matthiessen.
Cobalt	–	9.8	0	"
Copper	Annealed	1.55–1.63	0	Various.
"	Hard-drawn	1.61–1.68	0	"
Iron	Commercial	9.7–12.0	0	"
"	Electrolytic	11.2	Ordinary	Kohlrausch.
"	"	105.5	Red heat	"
"	"	114.8	Yellow heat	"
"	"	118.3	Iron magnetic heat	"
Steel	Cast	19.1	Ord. temp.	"
"	"	85.8	Red heat	"
"	"	104.4	Yellow heat	"
"	"	113.9	Nearly white heat	"
"	Tempered glass hard	$45.7\ (1 + .00161t)$	t	Barus and Strouhal.
"	" light yellow	$28.9\ (1 + .00244t)$	t	" "
"	" yellow	$26.3\ (1 + .00280t)$	t	" "
"	" blue	$20.5\ (1 + .00330t)$	t	" "
"	" light blue	$18.4\ (1 + .00360t)$	t	" "
"	" soft	$15.9\ (1 + .00423t)$	t	" "
Iron	Cast, hard	97.8	0	" "
"	" soft	74.4	0	" "
Indium	–	8.38	0	Erhard.
Lead	–	18.4–19.6	0	Various.
Lithium	–	8.8	20	Matthiessen.
Magnesium	–	4.1–5.0	0	Various.
Nickel	–	10.7–12.4	0	"
Palladium	–	10.6–13.6	0	"
Platinum	–	9.0–15.5	0	"
Potassium	–	25.1	0	Matthiessen.
"	Fluid	50.4	100	"
Silver	–	1.5–1.7	0	Various.
Strontium	–	25.13	20	Matthiessen.
Tellurium	–	2.17×10^5	19.6	"
"	–	55.05	294	Vincentini and Omodei.
Tin	–	9.53–11.4	0	Various.
"	–	9.53	0	Vassura.
"	Solid	20.96	226.5	"
"	Liquid	44.56	226.5	"
Zinc	–	5.56–6.04	0	
"	Solid	18.16	Melting-point	De la Rive.
"	Liquid	36.00	"	"

RESISTANCE OF METALS A

The electrical resistance of some pure metals and of some alloys have been determined by Dewar and Flemi increases as the temperature is lowered. The resistance seems to approach zero for the pure metals, but n temperature tried. The following table gives the results of Dewar and Fleming.*

When the temperature is raised above 0° C. the coefficient decreases for the pure metals, as is shown by the e experiments to be approximately true, namely, that the resistance of any pure metal is proportional to its ab is greater the lower the temperature, because the total resistance is smaller. This rule, however, does no zero Centigrade, as is shown in the tables of resistance of alloys. (Cf. Table 262.)

Temperature =	100°	20°	0°	−8
Metal or alloy.	Specific resistance in c. g. s. units.			
Aluminium, pure hard-drawn wire	4745	3505	3161	–
Copper, pure electrolytic and annealed	1920	1457	1349	–
Gold, soft wire	2665	2081	1948	14
Iron, pure soft wire	13970†	9521	8613	–
Nickel, pure (prepared by Mond's process from compound of nickel and carbon monoxide)	19300	13494	12266	74
Platinum, annealed	10907	8752	8221	61
Silver, pure wire	2139	1647	1559	11
Tin, pure wire	13867	10473	9575	66
German silver, commercial wire	35720	34707	34524	336
Palladium-silver, 20 Pd + 80 Ag	15410	14984	14961	144
Phosphor-bronze, commercial wire	9071	8588	8479	80
Platinoid, Martino's platinoid with 1 to 2% tungsten	44590	43823	43601	430
Platinum-iridium, 80 Pt + 20 Ir	31848	29902	29374	275
Platinum-rhodium, 90 Pt + 10 Rh	18417	14586	13755	107
Platinum-silver, 66.7 Ag + 33.3 Pt	27404	26915	26818	263
Carbon, from Edison-Swan incandescent lamp	–	4046×10^3	4092×10^3	$4189\times$
Carbon, from Edison-Swan incandescent lamp	3834×10^3	3908×10^3	3955×10^3	$4054\times$
Carbon, adamantine, from Woodhouse and Rawson incandescent lamp	6168×10^3	6300×10^3	6363×10^3	$6495\times$

* "Phil. Mag." vol. 34, 1892.

† This is given by Dewar and Fleming as 13777 for 96°.4, which appears from the other measurements too h

ALLOYS AT LOW TEMPERATURES.

by Cailletet and Bouty at very low temperatures. The results show that the coefficient of change with temperature the alloys. The resistance of carbon was found by Dewar and Fleming to increase continuously to the lowest

ments or Müller, Benoit, and others. Probably the simplest rule is that suggested by Clausius, and shown by these temperature. This gives the actual change of resistance per degree, a constant; and hence the percentage of change approximately hold for alloys, some of which have a negative temperature coefficient at temperatures not far from

Temperature =	−100°	−182°	−197°	Mean value of temperature coefficient between −100° and +100° C.*
Metal or alloy.	Specific resistance in c. g. s. units.			
Aluminum, pure hard-drawn wire	1928	894	–	.00446
Copper, pure electrolytic and annealed	757	272	178	431
Gold, soft wire	1207	604	–	375
Iron, pure soft wire	4010	1067	608	578
Nickel, pure (prepared by Mond's process from compound of nickel and carbon monoxide)	6110	1900	–	538
Platinum, annealed	5295	2821	2290	341
Silver, pure wire	962	472	–	377
Tin, pure wire	5671	2553	–	428
German silver, commercial wire	33280	32512	–	035
Palladium-silver, 20 Pd + 80 Ag	14256	13797	–	039
Phosphor-bronze, commercial wire	7883	7371	–	070
Platinoid, Martino's platinoid with 1 to 2% tungsten	42385	41454	–	025
Platinum-iridium, 80 Pt + 20 Ir	26712	24440	–	087
Platinum-rhodium, 90 Pt + 10 Rh	9834	7134	–	312
Platinum-silver, 66.7 Ag + 33.3 Pt	26108	25537	–	024
Carbon, from Edison-Swan incandescent lamp	4218×10^8	4321×10^8	–	–
Carbon, from Edison-Swan incandescent lamp	4079×10^8	4180×10^8	–	031
Carbon, adamantine, from Woodhouse and Rawson incandescent lamp	6533×10^8	–	–	029

* This is α in the equation $R = R_0(1 + \alpha t)$, as calculated from the equation $\alpha = \frac{R_{100} - R_{-100}}{200\, R_0}$.

CONDUCTIVITY OF THREE-METAL AND MISCELLANEOUS ALLOYS.

Conductivity in mhos or $\frac{1}{\text{ohms per cm. cube}} = C_t = C_o(1 - at + bt^2)$.

Metals and alloys.	Composition by weight.	$\frac{C_0}{10^4}$	$a \times 10^3$	$b \times 10^5$	Authority.
Gold-copper-silver	58.3 Au + 26.5 Cu + 15.2 Ag	7.58	574	924	1
" " "	66.5 Au + 15.4 Cu + 18.1 Ag	6.83	529	93	1
" " "	7.4 Au + 78.3 Cu + 14.3 Ag	28.06	1830	7280	1
Nickel-copper-zinc	12.84 Ni + 30.59 Cu + 6.57 Zn by volume	4.92	444	51	1
Brass	Various	12.2–15.6	1–2 × 10^3	–	2
" hard drawn	70.2 Cu + 29.8 Zn	12.16	–	–	3
" annealed	" "	14.35	–	–	3
German silver	Various	3–5	–	–	2
" "	60.16 Cu + 25.37 Zn + 14.03 Ni + .30 Fe with trace of cobalt and manganese	3.33	360	–	4
Aluminum bronze	– – –	7.5–8.5	5–7 × 10^2	–	2
Phosphor bronze	– – –	10–20	–	–	2
Silicium bronze	– – –	41	–	–	5
Manganese-copper	30 Mn + 70 Cu	1.00	40	–	4
Nickel-manganese-copper	3 Ni + 24 Mn + 73 Cu	2.10	—30	–	4
Nickelin	18.46 Ni + 61.63 Cu + 19.67 Zn + 0.24 Fe + 0.19 Co + 0.18 Mn	3.01	300	–	4
Patent nickel	25.1 Ni + 74.41 Cu + 0.42 Fe + 0.23 Zn + 0.13 Mn + trace of cobalt	2.92	190	–	4
Rheotan	53.28 Cu + 25.31 Ni + 16.89 Zn + 4.46 Fe + 0.37 Mn	1.90	410	–	4
Copper-manganese-iron	91 Cu + 7.1 Mn + 1.9 Fe	4.98	120	–	6
" " "	70.6 Cu + 23.2 Mn + 6.2 Fe	1.30	22	–	6
" " "	69.7 Cu + 29.9 Ni + 0.3 Fe	2.60	120	–	7
Manganin	84 Cu + 12 Mn + 4 Ni	2.3	0–42	300–600	2
Constantan	60 Cu + 40 Ni	2.04	18	–	8

1 Matthiessen. 2 Various. 3 W. Siemens. 4 Feussner and Lindeck. 5 Van der Ven. 6 Blood. 6 Feussner. 7 Jaeger-Diesselhorst.

CONDUCTING POWER OF ALLOYS.

table shows the conducting power of alloys and the variation of the conducting power with temperature.* The ues of C_0 were obtained from the original results by assuming silver $= \frac{10^6}{1.585}$ mhos. The conductivity is taken $C_t = C_0(1 - at + \delta t^2)$, and the range of temperature was from 0° to 100° C.

table is arranged in three groups to show (1) that certain metals when melted together produce a solution hich has a conductivity equal to the mean of the conductivities of the components, (2) the behavior of those etals alloyed with others, and (3) the behavior of the other metals alloyed together.

ointed out that, with a few exceptions, the percentage variation between 0° and 100° can be calculated from the rmula $P = P_c \frac{l}{l'}$, where l is the observed and l' the calculated conducting power of the mixture at 100° C., d P_c is the calculated mean variation of the metals mixed.

Alloys.	Weight % of first named.	Volume % of first named.	$\frac{C_0}{10^4}$	$a \times 10^6$	$\delta \times 10^9$	Variation per 100° C. Observed.	Variation per 100° C. Calculated.
GROUP 1.							
$_6$Pb	77.04	83.96	7.57	3890	8670	30.18	29.67
$_4$Cd	82.41	83.10	9.18	4080	11870	28.89	30.03
Zn	78.06	77.71	10.56	3880	8720	30.12	30.16
Sn	64.13	53.41	6.40	3780	8420	29.41	29.10
Cd_2	24.76	26.06	16.16	3780	8000	29.86	29.67
Cd_4	23.05	23.50	13.67	3850	9410	29.08	30.25
Pb_6	7.37	10.57	5.78	3500	7270	27.74	27.60
GROUP 2.							
ead-silver ($Pb_{20}Ag$)	95.05	94.64	5.60	3630	7960	28.24	19.96
ead-silver ($PbAg$)	48.97	46.90	8.03	1960	3100	16.53	7.73
ead-silver ($PbAg_2$)	32.44	30.64	13.80	1990	2600	17.36	10.42
n-gold ($Sn_{12}Au$)	77.94	90.32	5.20	3080	6640	24.20	14.83
" " (Sn_6Au)	59.54	79.54	3.03	2920	6300	22.90	5.95
n-copper	92.24	93.57	7.59	3680	8130	28.71	19.76
" " †	80.58	83.60	8.05	3330	6840	26.24	14.57
" " †	12.49	14.91	5.57	547	294	5.18	3.99
" " †	10.30	12.35	6.41	666	1185	5.48	4.46
" " †	9.67	11.61	7.64	691	304	6.60	5.22
" " †	4.96	6.02	12.44	995	705	9.25	7.83
" " †	1.15	1.41	39.41	2670	5070	21.74	20.53
n-silver	91.30	96.52	7.81	3820	8190	30.00	23.31
" "	53.85	75.51	8.65	3770	8550	29.18	11.89
nc-copper †	36.70	42.06	13.75	1370	1340	12.40	11.29
" " †	25.00	29.45	13.70	1270	1240	11.49	10.08
" " †	16.53	23.61	13.44	1880	1800	12.80	12.30
" " †	8.89	10.88	29.61	2040	3030	17.41	17.42
" " †	4.06	5.03	38.09	2470	4100	20.61	20.62

TE. — Barus, in the "Am. Jour. of Sci." vol. 36, has pointed out that the temperature variation of platinum containing less than 10% of the other metal can be nearly expressed by an equation $y = \frac{n}{x} - m$, where y is the erature coefficient and x the specific resistance, m and n being constants. If a be the temperature coefficient at and s the corresponding specific resistance, $s(a + m) = n$.

For platinum alloys Barus's experiments gave $m = -.000194$ and $n = .0378$.
For steel $m = -.000303$ and $n = .0620$.

atthiessen's experiments reduced by Barus gave for

Gold alloys $m = -.000045$, $n = .00721$.
Silver " $m = -.000112$, $n = .00538$.
Copper " $m = -.000386$, $n = .00555$.

* From the experiments of Matthiessen and Vogt, "Phil. Trans. R. S." v. 154.
† Hard-drawn.

CONDUCTING POWER OF ALLOYS.

Alloys.	Weight % of first named.	Volume % of first named.	$\frac{C_0}{10^4}$	$a \times 10^8$	$b \times 10^9$	Variation per 100° C. Observed.	Variation per 100° C. Calculated.
Group 3.							
Gold-copper †	99.23	98.36	35.42	2650	4650	21.87	23.22
" " †	90.55	81.66	10.16	749	81	7.41	7.53
Gold-silver †	87.95	79.86	13.46	1090	793	10.09	9.65
" " *	87.95	79.86	13.61	1140	1160	10.21	9.59
" " †	64.80	52.08	9.48	673	246	6.49	6.58
" " *	64.80	52.08	9.51	721	495	6.71	6.42
" " †	31.33	19.86	13.69	885	531	8.23	8.62
" " *	31.33	19.86	13.73	908	641	8.44	8.31
Gold-copper †	34.83	19.17	12.94	864	570	8.07	8.18
" " †	1.52	0.71	53.02	3320	7300	25.90	25.86
Platinum-silver †	33.33	19.65	4.22	330	208	3.10	3.21
" " †	9.81	5.05	11.38	774	656	7.08	7.25
" " †	5.00	2.51	19.96	1240	1150	11.29	11.88
Palladium-silver †	25.00	23.28	5.38	324	154	3.40	4.21
Copper-silver †	98.08	98.35	56.49	3450	7990	26.50	27.30
" " †	94.40	95.17	51.93	3250	6940	25.57	25.41
" " †	76.74	77.64	44.06	3030	6070	24.29	21.92
" " †	42.75	46.67	47.29	2870	5280	22.75	24.00
" " †	7.14	8.25	50.65	2750	4360	23.17	25.57
" " †	1.31	1.53	50.30	4120	8740	26.51	29.77
Iron-gold †	13.59	27.93	1.73	3490	7010	27.92	14.70
" " †	9.80	21.18	1.26	2970	1220	17.55	11.20
" " †	4.76	10.96	1.46	487	103	3.84	13.40
Iron-copper †	0.40	0.46	24.51	1550	2090	13.44	14.03
Phosphorus-copper †	2.50	–	4.62	476	145	–	–
" " †	0.95	–	14.91	1320	1640	–	–
Arsenic-copper †	5.40	–	3.97	516	989	–	–
" " †	2.80	–	8.12	736	446	–	–
" " †	trace	–	38.52	2640	4830	–	–

* Annealed. † Hard-drawn.

LECTRICAL RESISTANCE OF STRAIGHT WIRES WITH ALTERNATING CURRENTS OF DIFFERENT FREQUENCIES.

is table gives the ratio of the resistance of straight copper wires with alternating currents of different frequencies to the value of the resistance with direct currents.

Diameter of wire in millimeters.	Frequency n =					
	60	100	1000	10000	100000	1000000
0.05	–	–	–	–	–	*1.001
0.1	–	–	–	–	*1.001	1.008
0.25	–	–	–	–	1.003	1.247
0.5	–	–	–	*1.001	1.047	2.240
1.0	–	–	–	1.008	1.503	4.19
2	–	–	1.001	1.120	2.756	
3	–	–	1.006	1.437	4.00	
4	–	–	1.021	1.842		
5	–	*1.001	1.047	2.240		
7.5	1.001	1.002	1.210	3.22		
10	1.003	1.008	1.503	4.19		
15	1.016	1.038	2.136			
20	1.044	1.120	2.756			
25	1.105	1.247	3.38			
40	1.474	1.842				
100	3.31	4.19				

Values between 1.000 and 1.001 are indicated by *1.001.

The change of resistance of wires other than copper (iron wires excepted) may be calculated m the above table, making use of the fact that the change of resistance is a function of the gument $p = 2\pi r\sqrt{2n\lambda}$ where r = radius of cross-section, n = frequency, λ = conductivity.

If a given wire be wound into a solenoid, its resistance, at a given frequency, will be greater than e values in the table, which apply to straight wires only. The resistance in this case is a com- icated function of the pitch and radius of the winding, the frequency, and the diameter of the re, and is found by experiment to be sometimes as much as twice the value for a straight wire.

INTERNATIONAL ATOMIC WEIGHTS AND ELECTROCHEMICAL EQUIVALENTS.

The International Atomic Weights are quoted from the report of the International Commi on Atomic Weights ("Jour. Am. Chem. Soc.," vol. 32, p. 3, 1910).

With the exception of the value given for silver and that corresponding to valence 2 for cop the electrochemical equivalents given in this table have been calculated from the atomic wei and one or two of the more common apparent valences of the substance. The value given silver is that which was adopted by the International Congress of Electricians at Chicago in 1

Substance.	Symbol.	Relative atomic wt. Oxygen = 16.	Relative atomic wt. Hydrogen = 1.	Valence.	Electrochemical equivalent in gramm per coulomb × 1000
Aluminum	Al	27.1	26.9	3	.0936
Antimony	Sb	120.2	119.3	3	.4152
"	"	"	"	5	.2491
Argon	A	39.9	39.6	-	-
Arsenic	As	74.96	74.4	3	.2590
"	"	"	"	5	.1554
Barium	Ba	137.37	136.27	2	.7118
Bismuth	Bi	208.0	206.3	3	.7185
"	"	"	"	5	.4311
Boron	B	11.0	10.9	3	.0380
Bromine	Br	79.92	79.28	1	.8282
Cadmium	Cd	112.40	111.51	2	0.5824
Cæsium	Cs	132.81	131.76	1	1.3764
Calcium	Ca	40.09	39.77	2	0.2077
Carbon	C	12.00	11.99	4	.0313
Cerium	Ce	140.25	139.14	2	.7267
Chlorine	Cl	35.46	35.19	1	.3675
Chromium	Cr	52.0	51.6	3	.1797
"	"	"	"	6	.0900
Cobalt	Co	58.97	58.50	2	.3061
"	"	"	"	3	.2041
Columbium	Cb	93.5	92.8	5	.1937
Copper	Cu	63.57	63.07	1	.6588
"	"	"	"	2	.3290
Dysprosium	Dy	162.5	161.2	-	-
Erbium	Er	167.4	166.1	2	.8624
Europium	Eu	152.0	150.8	-	-
Fluorine	F	19.0	18.9	1	.1968
Gadolinium	Gd	157.3	156.1	-	-
Gallium	Ga	69.9	69.3	3	.2414
Germanium	Ge	72.5	71.9	-	-
Glucinum	Gl	9.1	9.03	2	.0471
Gold	Au	197.2	195.7	3	.6818
Helium	He	4.0	4.0	-	-
Hydrogen	H	1.008	1.000	1	.0104
Indium	In	114.8	113.9	3	0.3966
Iodine	I	126.92	125.91	1	1.3153
Iridium	Ir	193.1	191.6	4	0.5003
Iron	Fe	55.85	55.41	2	.2894
"	"	"	"	3	.1929
Krypton	Kr	83.0	82.4	-	-
Lanthanum	La	139.0	137.9	2	0.7202
Lead	Pb	207.10	205.46	2	1.0731
Lithium	Li	7.00	6.94	1	0.0725
Lutecium	Lu	174.0	172.6	-	-
Magnesium	Mg	24.32	24.13	2	.1260
Manganese	Mn	54.93	54.49	2	.2846
"	"	"	"	4	.1423

INTERNATIONAL ATOMIC WEIGHTS AND ELECTROCHEMICAL EQUIVALENTS.

Substance.	Symbol.	Relative atomic wt. Oxygen = 16.	Relative atomic wt. Hydrogen = 1.	Valence.	Electrochemical equivalent in grammes per coulomb × 1000.
Mercury	Hg	200.0	198.5	1	2.0727
"	"	"	"	2	1.0363
Molybdenum	Mo	96.0	95.3	6	0.1658
Neodymium	Nd	144.3	143.2	–	–
Neon	Ne	20.0	19.9	–	–
Nickel	Ni	58.68	58.21	2	.3040
"	"	"	"	3	.2027
Nitrogen	N	14.01	13.90	3	.0484
"	"	"	"	5	.0290
Osmium	Os	190.9	189.4	6	.3297
Oxygen	O	16.00	15.88	2	.0829
Palladium	Pd	106.7	105.9	2	.5528
"	"	"	"	5	.2211
Phosphorus	P	31.0	30.8	3	.1071
"	"	"	"	5	0.0642
Platinum	Pt	195.0	193.4	2	1.0104
"	"	"	"	4	0.5052
Potassium	K	39.10	38.79	1	.4052
Præsodymium	Pr	140.6	139.5	–	–
Radium	Rd	226.4	224.6	–	–
Rhodium	Rh	102.9	102.1	3	.3554
Rubidium	Rb	85.45	84.77	1	.8855
Ruthenium	Ru	101.7	100.9	4	.2635
Samarium	Sa	150.4	149.2	–	–
Scandium	Sc	44.1	43.7	–	–
Selenium	Se	79.2	78.6	2	.4104
Silicon	Si	28.3	28.2	4	0.0733
Silver	Ag	107.88	107.02	1	1.1180
Sodium	Na	23.00	22.82	1	0.2384
Strontium	Sr	87.62	86.92	2	.4540
Sulphur	S	32.07	31.82	2	.1662
Tantalum	Ta	181.0	179.6	5	.3751
Tellurium	Te	127.5	126.5	2	0.6606
Terbium	Tb	159.2	157.9	–	–
Thallium	Tl	204.0	202.4	1	2.1141
Thorium	Th	232.42	230.57	2	1.2043
Thulium	Tm	168.5	167.2	–	–
Tin	Sn	119.0	118.1	2	0.6166
"	"	"	"	4	.3083
Titanium	Ti	48.1	47.7	4	.1246
Tungsten	W	184.	183.	6	0.3178
Uranium	U	238.5	236.6	2	1.2358
"	"	"	"	3	0.8238
Vanadium	V	51.2	50.8	3	.1768
"	"	"	"	5	.1061
Xenon	Xe	130.7	129.7	–	–
Ytterbium	Yb	172.0	170.6	–	–
Yttrium	Yt	89.0	88.3	2	.4611
Zinc	Zn	65.37	64.88	2	.3385
Zirconium	Zr	90.6	89.9	4	.2347

CONDUCTIVITY OF ELECTROLYTIC SOLUTIONS.

This subject has occupied the attention of a considerable number of eminent workers in molecular physics, and a few results are here tabulated. It has seemed better to confine the examples to the work of one experimenter, and the tables are quoted from a paper by F. Kohlrausch,* who has been one of the most reliable and successful workers in this field.

The study of electrolytic conductivity, especially in the case of very dilute solutions, has furnished material for generalizations, which may to some extent help in the formation of a sound theory of the mechanism of such conduction. If the solutions are made such that per unit volume of the solvent medium there are contained amounts of the salt proportional to its electrochemical equivalent, some simple relations become apparent. The solutions used by Kohlrausch were therefore made by taking numbers of grammes of the pure salts proportional to their electrochemical equivalent, and using a litre of water as the standard quantity of the solvent. Taking the electrochemical equivalent number as the chemical equivalent or atomic weight divided by the valence, and using this number of grammes to the litre of water, we get what is called the normal or gramme molecule per litre solution. In the table, m is used to represent the number of gramme molecules to the litre of water in the solution for which the conductivities are tabulated. The conductivities were obtained by measuring the resistance of a cell filled with the solution by means of a Wheatstone bridge alternating current and telephone arrangement. The results are for 18° C., and relative to mercury at 0° C., the cell having been standardized by filling with mercury and measuring the resistance. They are supposed to be accurate to within one per cent of the true value.

The tabular numbers were obtained from the measurements in the following manner:—

Let K_{18} = conductivity of the solution at 18° C. relative to mercury at 0° C.

K^{w}_{18} = conductivity of the solvent water at 18° C. relative to mercury at 0° C.

Then $K_{18} - K^{w}_{18} = k_{18}$ = conductivity of the electrolyte in the solution measured.

$\frac{k_{18}}{m} = \mu$ = conductivity of the electrolyte in the solution per molecule, or the "specific molecular conductivity."

TABLE 277.—Value of k_{18} for a few Electrolytes.

This short table illustrates the apparent law that the conductivity in very dilute solutions is proportional to the amount of salt dissolved.

m	KCl	NaCl	$AgNO_3$	$KC_2H_3O_2$	K_2SO_4	$MgSO_4$
0.000001	1.216	1.024	1.080	0.939	1.275	1.056
0.00002	2.434	2.056	2.146	1.886	2.532	2.104
0.00006	7.272	6.162	6.462	5.610	7.524	6.216
0.0001	12.09	10.29	10.78	9.34	12.49	10.34

TABLE 278.—Electro-Chemical Equivalents and Normal Solutions.

The following table of the electro-chemical equivalent numbers and the densities of approximately normal solutions of the salts quoted in Table 271 may be convenient. They represent grammes per cubic centimetre of the solution at the temperature given.

Salt dissolved.	Grammes per litre.	m	Temp. C.	Density.	Salt dissolved.	Grammes per litre.	m	Temp. C.	Density.
KCl . . .	74.59	1.0	15.2	1.0457	$\frac{1}{2}K_2SO_4$.	87.16	1.0	18.9	1.0658
NH_4Cl . .	53.55	1.0009	18.6	1.0152	$\frac{1}{2}Na_2SO_4$.	71.09	1.0003	18.6	1.0602
NaCl . . .	58.50	1.0	18.4	1.0391	$\frac{1}{2}Li_2SO_4$.	55.09	1.0007	18.6	1.0445
LiCl . . .	42.48	1.0	18.4	1.0227	$\frac{1}{2}MgSO_4$.	60.17	1.0023	18.6	1.0573
$\frac{1}{2}BaCl_2$ . .	104.0	1.0	18.6	1.0888	$\frac{1}{2}ZnSO_4$.	80.58	1.0	5.3	1.0794
$\frac{1}{2}ZnCl_2$ . .	68.0	1.012	15.0	1.0592	$\frac{1}{2}CuSO_4$.	79.9	1.001	18.2	1.0776
KI	165.9	1.0	18.6	1.1183	$\frac{1}{2}K_2CO_3$.	69.17	1.0006	18.3	1.0576
KNO_3 . .	101.17	1.0	18.6	1.0601	$\frac{1}{2}Na_2CO_3$.	53.04	1.0	17.9	1.0517
$NaNO_3$ . .	85.08	1.0	18.7	1.0542	KOH . .	56.27	1.0025	18.8	1.0477
$AgNO_3$ . .	169.9	1.0	–	–	HCl . .	36.51	1.0041	18.6	1.0161
$\frac{1}{2}Ba(NO_3)_2$.	65.28	0.5	–	–	HNO_3 . .	63.13	1.0014	18.6	1.0318
$KClO_3$ . .	61.29	0.5	18.3	1.0367	$\frac{1}{2}H_2SO_4$.	49.06	1.0006	18.9	1.0300
$KC_2H_3O_2$.	98.18	1.0005	18.6	1.0467					

* "Wied. Ann." vol. 26, pp. 161–226.

SPECIFIC MOLECULAR CONDUCTIVITY μ: MERCURY = 10^8.

Salt dissolved.	$m=10$	5	3	1	0.5	0.1	.05	.03	.01
$\frac{1}{2}K_2SO_4$	–	–	–	–	672	736	897	959	1098
KCl	–	–	827	919	958	1047	1083	1107	1147
KI	–	770	900	968	997	1069	1102	1123	1161
NH_4Cl	–	752	825	907	948	1035	1078	1101	1142
KNO_3	–	–	572	752	839	983	1037	1067	1122
$\frac{1}{2}BaCl_2$	–	–	487	658	725	861	904	939	1006
$KClO_3$	–	–	–	–	799	927	(976)	1006	1053
$\frac{1}{2}Ba_2N_2O_6$	–	–	–	–	531	755	828	(870)	951
$\frac{1}{2}CuSO_4$	–	–	150	241	288	424	479	537	675
$AgNO_3$	–	351	448	635	728	886	936	(966)	1017
$\frac{1}{2}ZnSO_4$	–	82	146	249	302	431	500	556	685
$\frac{1}{2}MgSO_4$	–	82	151	270	330	474	532	587	715
$\frac{1}{2}Na_2SO_4$	–	–	–	475	559	734	784	828	906
$\frac{1}{2}ZnCl_2$	60	180	280	514	601	768	817	851	915
NaCl	–	398	528	695	757	865	897	(920)	962
$NaNO_3$	–	–	430	617	694	817	855	877	907
$KC_2H_3O_2$	30	240	381	594	671	784	820	841	879
$\frac{1}{2}Na_2CO_3$	–	–	254	427	510	682	751	799	899
$\frac{1}{2}H_2SO_4$	660	1270	1560	1820	1899	2084	2343	2515	2855
C_2H_4O	0.5	2.6	5.2	12	19	43	62	79	132
HCl	600	1420	2010	2780	3017	3244	3330	3369	3416
HNO_3	610	1470	2070	2770	2991	3225	3289	3328	3395
$\frac{1}{3}H_3PO_4$	148	160	170	200	250	430	540	620	790
KOH	423	990	1314	1718	1841	1986	2045	2078	2124
NH_3	0.5	2.4	3.3	8.4	12	31	43	50	92

Salt dissolved.	.006	.002	.001	.0006	.0002	.0001	.00006	.00002	.00001
$\frac{1}{2}K_2SO_4$	1130	1181	1207	1220	1241	1249	1254	1266	1275
KCl	1162	1185	1193	1199	1209	1209	1212	1217	1216
KI	1176	1197	1203	1209	1214	1216	1216	1216	1207
NH_4Cl	1157	1180	1190	1197	1204	1209	1215	1209	1205
KNO_3	1140	1173	1180	1190	1199	1207	1220	1198	1215
$\frac{1}{2}BaCl_2$	1031	1074	1092	1102	1118	1126	1133	1144	1142
$KClO_3$	1068	1091	1101	1109	1119	1122	1126	1135	1141
$\frac{1}{2}Ba_2N_2O_6$	982	1033	1054	1066	1084	1096	1100	1114	1114
$\frac{1}{2}CuSO_4$	740	873	950	987	1039	1062	1074	1084	1086
$AgNO_3$	1033	1057	1068	1069	1077	1078	1077	1073	1080
$\frac{1}{2}ZnSO_4$	744	861	919	953	1001	1023	1032	1047	1060
$\frac{1}{2}MgSO_4$	773	881	935	967	1015	1034	1036	1052	1056
$\frac{1}{2}Na_2SO_4$	933	980	998	1009	1026	1034	1038	1056	1054
$\frac{1}{2}ZnCl_2$	939	979	994	1004	1020	1029	1031	1035	1036
NaCl	976	998	1008	1014	1018	1029	1027	1028	1024
$NaNO_3$	921	942	952	956	966	975	970	972	975
$KC_2H_3O_2$	891	913	919	923	933	934	935	943	939
$\frac{1}{2}Na_2CO_3$	956	1010	1037	1046	988	874	790	715	697*
$\frac{1}{2}H_2SO_4$	3001	3240	3316	3342	3280	3118	2927	2077	1413*
C_2H_4O	170	283	380	470	796	995	1133	1328	1304*
HCl	3438	3455	3455	3440	3340	3170	2968	2057	1254*
HNO_3	3421	3448	3427	3408	3285	3088	2863	1904	1144*
$\frac{1}{3}H_3PO_4$	858	945	968	977	920	837	746	497	402*
KOH	2141	2140	2110	2074	1892	1689	1474	845	747*
NH_3	116	190	260	330	500	610	690	700	560*

* Acids and alkaline salts show peculiar irregularities.

LIMITING VALUES OF μ. TEMPERATURE COEFFICIENTS.

TABLE 280. — Limiting Values of μ.

This table shows limiting values of $\mu = \frac{k}{m} \cdot 10^8$ for infinite dilution for neutral salts, calculated from Table 271.

Salt.	μ	Salt.	μ	Salt.	μ	Salt.	μ
$\frac{1}{2}K_2SO_4$.	1280	$\frac{1}{2}BaCl_2$.	1150	$\frac{1}{2}MgSO_4$.	1080	$\frac{1}{2}H_2SO_4$.	3700
KCl . . .	1220	$\frac{1}{2}KClO_3$.	1150	$\frac{1}{2}Na_2SO_4$.	1060	HCl . .	3500
KI . . .	1220	$\frac{1}{2}BaN_2O_6$.	1120	$\frac{1}{2}ZnCl$ . .	1040	HNO_3 . .	3500
NH_4Cl . .	1210	$\frac{1}{2}CuSO_4$.	1100	NaCl . .	1030	$\frac{1}{3}H_3PO_4$.	1100
KNO_3 . .	1210	$AgNO_3$.	1090	$NaNO_3$.	980	KOH . .	2200
–	–	$\frac{1}{2}ZnSO_4$.	1080	$K_2C_2H_3O_2$	940	$\frac{1}{2}Na_2CO_3$.	1400

If the quantities in Table 271 be represented by curves, it appears that the values of the specific molecular conductivities tend toward a limiting value as the solution is made more and more dilute. Although these values are of the same order of magnitude, they are not equal, but depend on the nature of both the ions forming the electrolyte.

When the numbers in Table 272 are multiplied by Hittorf's constant, or 0.00011, quantities ranging between 0.14 and 0.10 are obtained which represent the velocities in millimetres per second of the ions when the electromotive force gradient is one volt per millimetre.

Specific molecular conductivities in general become less as the concentration is increased, which may be due to mutual interference. The decrease is not the same for different salts, but becomes much more rapid in salts of high valence.

Salts having acid or alkaline reactions show marked differences. They have small specific molecular conductivity in very dilute solutions, but as the concentration is increased the conductivity rises, reaches a maximum and again falls off. Kohlrausch does not believe that this can be explained by impurities. H_3PO_4 in dilute solution seems to approach a monobasic acid, while H_2SO_4 shows two maxima, and like H_3PO_4 approaches in very weak solution to a monobasic acid.

Kohlrausch concludes that the law of independent migration of the ions in media like water is sustained.

TABLE 281. — Temperature Coefficients.

The temperature coefficient in general diminishes with dilution, and for very dilute solutions appears to approach a common value. The following table gives the temperature coefficient for solutions containing 0.01 gramme molecule of the salt.

Salt.	Temp. Coeff.	Salt.	Temp. Coeff.	Salt.	Temp. Coeff.	Salt.	Temp. Coeff.
KCl . . .	0.0221	KI . . .	0.0219	$\frac{1}{2}K_2SO_4$.	0.0223	$\frac{1}{2}K_2CO_3$ . .	0.0249
NH_4Cl . .	0.0226	KNO_3 . .	0.0216	$\frac{1}{2}Na_2SO_4$.	0.0240	$\frac{1}{2}Na_2CO_3$ . .	0.0265
NaCl . .	0.0238	$NaNO_3$ . .	0.0226	$\frac{1}{2}Li_2SO_4$.	0.0242	KOH . . .	0.0194
LiCl . . .	0.0232	$AgNO_3$ . .	0.0221	$\frac{1}{2}MgSO_4$.	0.0236	HCl . . .	0.0159
$\frac{1}{2}BaCl_2$ . .	0.0234	$\frac{1}{2}Ba(NO_3)_2$	0.0224	$\frac{1}{2}ZnSO_4$.	0.0234	HNO_3 . . .	0.0162
$\frac{1}{2}ZnCl_2$ . .	0.0239	$KClO_3$ . .	0.0219	$\frac{1}{2}CuSO_4$.	0.0229	$\frac{1}{2}H_2SO_4$ . .	0.0125
$\frac{1}{2}MgCl_2$.	0.0241	$KC_2H_3O_2$.	0.0229	–	–	$\frac{1}{2}H_2SO_4$ for $m = .001$	0.0159

THE EQUIVALENT CONDUCTIVITY OF SALTS, ACIDS AND BASES IN AQUEOUS SOLUTIONS.

In the following table the equivalent conductance is expressed in reciprocal ohms. The concentration is expressed in milli-equivalents of solute per litre of solution at the temperature to which the conductance refers. (In the cases of potassium hydrogen sulphate and phosphoric acid the concentration is expressed in milli-formula-weights of solute, $KHSO_4$ or H_3PO_4, per litre of solution, and the values are correspondingly the modal, or "formal," conductances.) Except in the cases of the strong acids the conductance of the water was subtracted, and for sodium acetate, ammonium acetate and ammonium chloride the values have been corrected for the hydrolysis of the salts. The atomic weights used were those of the International Commission for 1905, referred to oxygen as 16.00. Temperatures are on the hydrogen gas scale.

$$\text{Concentration in } \frac{\text{gramme equivalents}}{\text{1000 litre}}.$$

$$\text{Equivalent conductance in } \frac{\text{reciprocal ohms per centimetre cube}}{\text{gramme equivalents per cubic centimetre}}.$$

Substance.	Concentration.	Equivalent conductance at the following °C temperatures.									
		18°	25°	50°	75°	100°	128°	156°	218°	281°	306°
Potassium chloride	0	130.1	(152.1)	(232.5)	(321.5)	414	(519)	625	825	1005	1120
" "	2	126.3	146.4	–	–	393	–	588	779	930	1008
" "	10	122.4	141.5	215.2	295.2	377	470	560	741	874	910
" "	80	113.5	–	–	–	342	–	498	638	723	720
" "	100	112.0	129.0	194.5	264.6	336	415	490			
Sodium chloride	0	109.0	–	–	–	362	–	555	760	970	1080
" "	2	105.6	–	–	–	349	–	534	722	895	955
" "	10	102.0	–	–	–	336	–	511	685	820	860
" "	80	93.5	–	–	–	301	–	450	500	674	680
" "	100	92.0	–	–	–	296	–	442			
Silver nitrate	0	115.8	–	–	–	367	–	570	780	965	1065
" "	2	112.2	–	–	–	353	–	539	727	877	935
" "	10	108.0	–	–	–	337	–	507	673	790	818
" "	20	105.1	–	–	–	326	–	488	639		
" "	40	101.3	–	–	–	312	–	462	599	680	680
" "	80	96.5	–	–	–	294	–	432	552	614	604
" "	100	94.6	–	–	–	289					
Sodium acetate	0	78.1	–	–	–	285	–	450	660	–	924
" "	2	74.5	–	–	–	268	–	421	578	–	801
" "	10	71.2	–	–	–	253	–	396	542	–	702
" "	80	63.4	–	–	–	221	–	340	452		
Magnesium sulphate	0	114.1	–	–	–	426	–	690	1080		
" "	2	94.3	–	–	–	302	–	377	260		
" "	10	76.1	–	–	–	234	–	241	143		
" "	20	67.5	–	–	–	190	–	195	110		
" "	40	59.3	–	–	–	160	–	158	88		
" "	80	52.0	–	–	–	136	–	133	75		
" "	100	49.8	–	–	–	130	–	126			
" "	200	43.1	–	–	–	110	–	109			
Ammonium chloride	0	131.1	152.0	–	–	(415)	–	(628)	(841)	–	(1176)
" "	2	126.5	146.5	–	–	399	–	601	801	–	1031
" "	10	122.5	141.7	–	–	382	–	573	758	–	925
" "	30	118.1	–	–	–	–	–	–	–	–	828
Ammonium acetate	0	(99.8)	–	–	–	(338)	–	(523)			
" "	10	91.7	–	–	–	300	–	456			
" "	25	88.2	–	–	–	286	–	426			

From the investigations of Noyes, Melcher, Cooper, Eastman and Kato; Journal of the American Chemical Society, 30, 1908.

THE EQUIVALENT CONDUCTIVITY OF SALTS, ACIDS AND BASES IN AQUEOUS SOLUTIONS.

Substance.	Concentration.	Equivalent conductance at the following °C temperatures.									
		18°	25°	38°	75°	100°	128°	156°	218°	281°	306°
Barium nitrate	0	1169	–	–	–	385	–	600	840	1120	1300
" "	2	109.7	–	–	–	352	–	536	715	828	824
" "	10	101.0	–	–	–	322	–	481	618	658	615
" "	40	88.7	–	–	–	280	–	412	507	503	448
" "	80	81.6	–	–	–	258	–	372	449	430	
" "	100	79.1	–	–	–	249					
Potassium sulphate	0	1328	–	–	–	455	–	715	1065	1460	1725
" "	2	124.8	–	–	–	402	–	605	806	893	867
" "	10	115.7	–	–	–	365	–	537	672	687	637
" "	40	104.2	–	–	–	320	–	455	545	519	466
" "	80	97.2	–	–	–	294	–	415	482	448	396
" "	100	95.0	–	–	–	286					
Hydrochloric acid	0	379.0	–	–	–	800	–	1085	1265	1380	1424
" "	2	373.6	–	–	–	826	–	1048	1217	1332	1337
" "	10	368.1	–	–	–	807	–	1016	1168	1226	1162
" "	80	353.0	–	–	–	762	–	946	1044	1046	862
" "	100	350.6	–	–	–	754	–	929	1006		
Nitric acid	0	377.0	421.0	570	706	826	945	1047	(1230)	–	(1380)
" "	2	371.2	413.7	559	690	806	919	1012	1166	–	1156
" "	10	365.0	406.0	548	676	786	893	978			
" "	50	353.7	393.3	528	649	750	845	917			
" "	100	346.4	385.0	516	632	728	817	880	–	–	454*
Sulphuric acid	0	383.0	(429)	(591)	(746)	891	(1042)	1176	1505	–	(2030)
" "	2	353.9	392.8	501	501	571	551	536	563	–	637
" "	10	309.0	337.0	406	435	446	460	481	533		
" "	50	253.5	273.0	323	356	384	417	448	502		
" "	100	233.3	251.2	300	336	369	404	435	483	–	474*
Potassium hydrogen sulphate	2	455.3	506.0	661.0	754	784	773	754			
	50	295.5	318.3	374.4	403	422	446	477			
	100	263.7	283.1	329.1	354	375	402	435			
Phosphoric acid	0	338.3	376	510	631	730	839	930			
" "	2	285.1	311.9	401	464	498	508	489			
" "	10	203.0	222.0	273	300	308	298	274			
" "	50	122.7	132.6	157.8	168.6	168	158	142			
" "	100	96.5	104.0	122.7	129.9	128	120	108			
Acetic acid	0	(347.0)	–	–	–	(773)	–	(980)	(1165)	–	(1268)
" "	10	14.50	–	–	–	25.1	–	22.2	14.7		
" "	30	8.50	–	–	–	14.7	–	13.0	8.65		
" "	80	5.22	–	–	–	9.05	–	8.00	5.34		
" "	100	4.67	–	–	–	8.10	–	–	4.82	–	1.57
Sodium hydroxide	0	216.5	–	–	–	594	–	835	1060		
" "	2	212.1	–	–	–	582	–	814			
" "	20	205.8	–	–	–	559	–	771	930		
" "	50	200.6	–	–	–	540	–	738	873		
Barium hydroxide	0	222	256	389	(520)	645	(760)	847			
" "	2	215	–	359	4	591					
" "	10	207	235	342	449	548	664	722			
" "	50	191.1	215.1	308	399	478	549	593			
" "	100	180.1	204.2	291	373	443	503	531			
Ammonium hydroxide	0	(238)	(271)	(404)	(526)	(647)	(764)	(908)	(1141)	–	(1406)
	10	9.66	–	–	–	23.2	–	22.3	15.6		
	30	5.66	–	–	–	13.6	–	13.0			
	100	3.10	3.62	5.35	6.70	7.47	–	7.17	4.82	–	1.33

* These values are at the concentration 80.0.

THE EQUIVALENT CONDUCTIVITY OF SOME ADDITIONAL SALTS IN AQUEOUS SOLUTION.

Conditions similar to those of the preceding table except that the atomic weights for 1908 were used.

Substance.	Concentration.	Equivalent conductance at the following ° C temperature.							
		0°	18°	25°	50°	75°	100°	128°	156°
Potassium nitrate	0	80.8	126.3	145.1	219	299	384	485	580
" "	2	78.6	122.5	140.7	212.7	289.9	370.3	460.7	551
" "	12.5	75.3	117.2	134.9	202.9	276.4	351.5	435.4	520.4
" "	50	70.7	109.7	126.3	189.5	257.4	326.1	402.9	476.1
" "	100	67.2	104.5	120.3	180.2	244.1	308.5	379.5	447.3
Potassium oxalate	0	79.4	127.6	147.5	230	322	419	538	653
" "	2	74.9	119.9	139.2	215.9	300.2	389.3	489.1	587
" "	12.5	69.3	111.1	129.2	199.1	275.1	354.1	438.8	524.3
" "	50	63	101	116.5	178.6	244.9	312.2	383.8	449.5
" "	100	59.3	94.6	109.5	167	227.5	288.9	353.2	409.7
" "	200	55.8	88.4	102.3	155	210.9	265.1	321.9	372.1
Calcium nitrate	0	70.4	112.7	130.6	202	282	369	474	575
" "	2	66.5	107.1	123.7	191.9	266.7	346.5	438.4	529.8
" "	12.5	61.6	98.6	114.5	176.2	244	314.6	394.5	473.7
" "	50	55.6	88.6	102.6	157.2	216.2	276.8	343	405.1
" "	100	51.9	82.6	95.8	146.1	199.9	255.5	315.1	369.1
" "	200	48.3	76.7	88.8	135.4	184.7	234.4	288	334.7
Potassium ferrocyanide	0	98.4	159.6	185.5	288	403	527		
" "	0.5	91.6	–	171.1					
" "	2.	84.8	137	158.9	243.8	335.2	427.6		
" "	12.5	71	113.4	131.6	200.3	271	340		
" "	50	58.2	93.7	108.6	163.3	219.5	272.4		
" "	100	53	84.9	98.4	148.1	198.1	245		
" "	200	48.8	77.8	90.1	135.7	180.6	222.3		
" "	400	45.4	72.1	83.3	124.8	165.7	203.1		
Barium ferrocyanide	0	91	150	176	277	393	521		
" "	2	46.9	75	86.2	127.5	166.2	202.3		
" "	12.5	30.4	48.8	56.5	83.1	107	129.8		
Calcium ferrocyanide	0	88	146	171	271	386	512		
" "	2	47.1	75.5	86.2	130				
" "	12.5	31.2	49.9	57.4					
" "	50	24.1	38.5	44.4	64.6	81.9			
" "	100	21.9	35.1	40.2	58.4	73.7	84.3		
" "	200	20.6	32.9	37.8	55	68.7	77.5		
" "	400	20.2	32.2	37.1	54	67.5	76.2		
Potassium citrate	0	76.4	124.6	144.5	228	320	420		
" "	0.5	–	120.1	139.4					
" "	2	71	115.4	134.5	210.1	293.8	381.2		
" "	5	67.6	109.9	128.2	198.7	276.5	357.2		
" "	12.5	62.9	101.8	118.7	183.6	254.2	326		
" "	50	54.4	87.8	102.1	157.5	215.5	273		
" "	100	50.2	80.8	93.9	143.7	196.5	247.5		
" "	300	43.5	69.8	81	123.5	167	209.5		
Lanthanum nitrate	0	75.4	122.7	142.6	223	313	413	534	651
" "	2	68.9	110.8	128.9	200.5	279.8	363.5	457.5	549
" "	12.5	61.4	98.5	114.4	176.7	243.4	311.2	383.4	447.8
" "	50	54	86.1	99.7	152.5	207.6	261.4	315.8	357.7
" "	100	49.9	79.4	91.8	139.5	189.1	236.7	282.5	316.3
" "	200	46	72.1	83.5	126.4	170.2	210.8	249.6	276.2

From the investigations of Noyes and Johnston, Journal of the American Chemical Society, 31, 1909.

CONDUCTANCE OF IONS. — HYDROLYSIS OF AMMONIUM ACETATE.

TABLE 284. — The Equivalent Conductance of the Separate Ions.

Ion	0°	18°	25°	50°	75°	100°	125°	156°
K	40.4	64.6	74.5	115	159	206	263	317
NH_4	40	63.5	50.9	82	116	155	203	249
NH_4	40.2	64.5	74.5	115	159	207	264	319
Ag	32.9	54.3	63.5	101	143	188	245	299
$\frac{1}{2}Ba$	33	55[a]	65	104	149	200	262	322
$\frac{1}{2}Ca$	30	51[a]	60	98	142	191	252	312
$\frac{1}{2}Sr$	33	61	72	119	173	235	312	388
Cl	41.1	65.5	75.5	116	160	207	264	318
NO_3	40.4	61.7	70.6	104	140	178	222	263
$C_2H_3O_2$	20.3	34.6	40.8	67	96	130	171	211
$\frac{1}{2}SO_4$	41	68[a]	79	125	177	234	303	370
$\frac{1}{2}CO_3$	39	63[a]	73	115	163	213	275	336
$\frac{1}{2}C_2O_4$	36	60	70	113	161	214		
$Fe(CN)_6$	58	98	111	173	244	321		
H	290	314	350	465	565	644	722	777
OH	105	170	192	284	360	439	525	592

Folin Johnson, Journ. Amer. Chem. Soc., 31, 1909.

TABLE 285. — Solubility of Ammonium Acetate and Ionization of Water.

Temperature, t	Solubility, Grams per 100 g. water	Ionization constant of water, $K_w \times 10^{14}$	Hydrogen-ion concentration in pure water. Equivalents per liter, $C_H \times 10^7$
0	—	0.089	0.30
18	(0.35)	0.46	0.68
25	—	0.82	0.91
100	48	48.	6.9
156	18.6	223.	14.9
218	52.7	461.	21.5
306	91.5	168.	13.0

Noyes, Kato, Kanolt, Sosman, No. 63 Publ. Carnegie Inst., Washington.

DIELECTRIC CONSTANTS.

TABLE 286. — Dielectric Constant (Specific Inductive Capacity) of Gases. Atmospheric Pressure.

Wave-lengths of the measuring current greater than 10000 cm.

Gas.	Temp. ° C.	Dielectric constant referred to		Authority.
		Vacuum=1	Air=1	
Air	0	1.000590	1.000000	Boltzmann, 1875.
"	–	1.000586	1.000000	Klemenčič, 1885.
Ammonia	20	1.00718	1.00659	Bädeker, 1901.
Carbon bisulphide	0	1.00290	1.00231	Klemenčič.
" "	100	1.00239	1.00180	Bädeker.
Carbon dioxide	0	1.000946	1.000356	Boltzmann.
" "	0	1.000985	1.000399	Klemenčič.
Carbon monoxide	0	1.000690	1.000100	Boltzmann.
" "	0	1.000695	1.000109	Klemenčič.
Ethylene	0	1.00131	1.00072	Boltzmann.
"	0	1.00146	1.00087	Klemenčič.
Hydrochloric acid	100	1.00258	1.00199	Bädeker.
Hydrogen	0	1.000264	0.999674	Boltzmann.
"	0	1.000264	0.999678	Klemenčič.
Methane	0	1.000944	1.000354	Boltzmann.
"	0	1.000953	1.000367	Klemenčič.
Nitrous oxide (N_2O)	0	1.00116	1.00057	Boltzmann.
" " "	0	1.00099	1.00041	Klemenčič.
Sulphur dioxide	0	1.00993	1.00934	Bädeker.
" "	0	1.00905	1.00846	Klemenčič.
Water vapor, 4 atmospheres	145	1.00705	1.00646	Bädeker.

TABLE 287. — Variation of the Dielectric Constant with the Temperature.

For variation with the pressure see next table.

If D_θ = the dielectric constant at the temperature $\theta°$ C., D_t at the temperature $t°$ C., and α and β are quantities given in the following table, then

$$D_\theta = D_t[1 - \alpha(t-\theta) + \beta(t-\theta)^2].$$

The temperature coefficients are due to Bädeker.

Gas.	α	β	Range of temp. ° C.
Ammonia	5.45×10^{-6}	2.59×10^{-7}	10 — 110
Sulphur dioxide	6.19×10^{-6}	1.86×10^{-7}	0 — 110
Water vapor	1.4×10^{-4}	–	145

The dielectric constant of air at atmospheric pressure but with varying temperature may also be calculated from the fact that $D - 1$ is approximately proportional to the density.

DIELECTRIC CONSTANTS (*continued*).

TABLE 288.—Change of the Dielectric Constant of Gases with the Pressure.

Gas.	Temperature, ° C.	Pressure atmos.	Dielectric constant.	Authority.
Air	19	20	1.0108	Tangl, 1907.
"	–	40	1.0218	" "
"	–	60	1.0330	" "
"	–	80	1.0439	" "
"	–	100	1.0548	" "
"	11	20	1.0101	Occhialini, 1905.
"	–	40	1.0196	" "
"	–	60	1.0294	" "
"	–	80	1.0387	" "
"	–	100	1.0482	" "
"	–	120	1.0579	" "
"	–	140	1.0674	" "
"	–	160	1.0760	" "
"	–	180	1.0845	" "
Carbon dioxide	15	10	1.008	Linde, 1895.
" "	–	20	1.020	" "
" "	–	40	1.060	" "
Nitrous oxide, N_2O	15	10	1.010	"
" " "	–	20	1.025	"
" " "	–	40	1.070	"

TABLE 289.—Dielectric Constants of Liquids.

A wave-length greater than 10000 centimetres is denoted by ∞.

Substance.	Temp. ° C.	Wave-length, cm.	Dielectric constant.	Authority.	Substance.	Temp. ° C.	Wave-length, cm.	Dielectric constant.	Authority.
Alcohol:					Alcohol:				
Amyl	frozen	∞	2.4	1	Methyl	−50	∞	45.3	1
"	−100	"	30.1	1	"	0	"	35.0	1
"	−50	"	23.0	1	"	+20	"	31.2	1
"	0	"	17.4	1	"	17	75	33.2	2
"	+20	"	16.0	1	Propyl	−120	∞	46.2	1
"	18	200	10.8	2	"	−60	"	33.7	1
"	18	73	4.7	2	"	0	"	24.8	1
Ethyl	frozen	∞	2.7	1	"	+20	"	22.2	1
"	−120	"	54.6	1	"	15	75	12.3	2
"	−80	"	44.3	1	Acetone	−80	∞	33.8	5
"	−40	"	35.3	1	"	0	"	26.6	5
"	0	"	28.4	1	"	15	1200	21.85	6
"	+20	"	25.8	1	"	17	73	20.7	7
"	17	200	24.4	2	Acetic acid	18	∞	9.7	8
"	"	75	23.0	2	" "	15	1200	10.3	6
"	"	53	20.6	3	" "	17	200	7.07	2
"	"	4	8.8	3	" "	19	75	6.29	2
"	"	0.4	5.0	4	Amyl acetate	19	∞	4.81	9
Methyl	frozen	∞	3.07	1	Amylene	16	"	2.20	10
"	−100	"	58.0	1					

References on page 281.

DIELECTRIC CONSTANTS OF LIQUIDS.

A wave-length greater than 10000 centimetres is desiguated by ∞.

Substance.	Temp. °C.	Wave-length cm.	Diel. const.	Author-ity.
lin	18	∞	7.316	11
zol (benzene) .	18	"	2.288	"
" .	19	73	2.26	2
mine	23	84	3.18	12
bon bisulphide	20	∞	2.626	13
" " .	17	73	2.64	2
oroform . . .	18	∞	5.2	11
" . . .	17	73	4.95	2
ane	14	∞	1.97	10
ylene . . .	17	"	2.24	"
yl ether . .	−80	∞	7.05	5
" . . .	−40	"	5.67	"
" . . .	0	"	4.68	"
" . . .	18	"	4.368	11
" . . .	20	"	4.30	13
" . . .	60	"	3.65	"
" . . .	100	"	3.12	"
" . . .	140	"	2.66	"
" . . .	180	"	2.12	"
	Crit. temp.			
" . . .	192	"	1.53	"
" . . .	18	83	4.35	14
mic acid . .	+2 (frozen)	73	19.0	2
" " . . .	15	1200	62.0	6
" " . . .	16	73	58.5	2
cerine . . .	15	1200	56.2	6
"	15	200	39.1	2
"	15	75	25.4	"
"	−	8.5	4.4	15
"	−	0.4	2.6	4
xane	17	∞	1.880	16
drogen perox-e 46 % in H_2O	18	75	84.7	17

Substance.	Temp. °C.	Wave-length cm.	Diel. const.	Author-ity.
	(frozen)			
Nitrobenzol . . .	−10	∞	9.9	1
" . . .	−5	"	42.0	"
" . . .	0	"	41.0	"
" . . .	+15	"	37.8	"
" . . .	30	"	35.1	"
" . . .	18	"	36.45	11
" . . .	17	73	34.0	2
Octane	17	∞	1.949	16
Oils :				
Almond . . .	20	∞	2.83	18
Castor	11	"	4.67	19
Colza	20	"	3.11	20
Cottonseed . .	14	"	3.10	21
Lemon	21	"	2.25	22
Linseed . . .	13	"	3.35	21
Neatsfoot . . .	−	"	3.02	20
Olive	20	"	3.11	23
Peanut	11.4	"	3.03	21
Petroleum . .	−	2000	2.13	24
Petroleum ether	20	∞	1.92	20
Rape seed . .	16	"	2.85	21
Sesame . . .	13.4	"	3.02	"
Sperm	20	"	3.17	20
Turpentine . .	20	"	2.23	"
Vaseline . . .	−	"	2.17	25
Phenol	48	73	9.68	2
Toluol	−83	∞	2.51	5
"	+16	"	2.33	"
"	19	73	2.31	2
Meta-xylol . . .	18	∞	2.37[6]	11
" " . . .	17	73	2.37	2
Water	18	∞	81.07	11
for temp. coeff.	17	200	80.6	2
see Table.	17	74	81.7	"
	17	38	83.6	"

Abegg-Seitz, 1899.
Drude, 1896.
Marx, 1898.
Lampa, 1896.
Abegg, 1897.
Thwing, 1894.
Drude, 1898.
Francke, 1893.
Löwe, 1898.
10 Landolt-Jahn, 1892.
11 Turner, 1900.
12 Schlundt.
13 Tangl, 1903.
14 Coolidge, 1899.
15 v. Lang, 1896.
16 Nernst, 1894.
17 Calvert, 1900.
18 Hasenöhrl, 1896.
19 Arons-Rubens, 1892.
20 Hopkinson, 1881.
21 Salvioni, 1888.
22 Tomaszewski, 1888.
23 Heinke, 1896.
24 Marx.
25 Fuchs.

DIELECTRIC CONSTANTS OF LIQUIDS (*continued*).

TABLE 290.—Temperature Coefficients of the Formula:

$$D_\theta = D_t[1-\alpha(t-\theta)+\beta(t-\theta)^2].$$

Substance.	α	β	Temp. range, °C.	Authority.
Amyl acetate	0.0024	–	–	Löwe.
Aniline	0.00351	–	–	Ratz.
Benzol	0.00106	0.0000087	10–40	Hasenöhrl.
Carbon bisulphide	0.000966	–	–	Ratz.
" "	0.000922	0.00000060	20–181	Tangl.
Chloroform	0.00410	0.000015	22–181	"
Ethyl ether	0.00459	–	–	Ratz.
Methyl alcohol	0.0057	–	–	Drude.
Oils: Almond	0.00163	0.000026	–	Hasenöhrl.
Castor	0.01067	–	–	Heinke, 1896.
Olive	0.00364	–	–	" "
Paraffine	0.000738	0.0000072	–	Hasenöhrl.
Toluol	0.000921	–	0–13	Ratz.
"	0.000977	0.00000046	20–181	Tangl.
Water	0.004474	–	5–20	Heerwagen.
"	0.004583	0.0000117	0–76	Drude.
"	0.00436	–	4–25	Coolidge.
Meta-xylol	0.000817	–	20–181	Tangl.

(See Table 287 for the signification of the letters.)

TABLE 291.—Dielectric Constants of Liquified Gases.

A wave-length greater than 10000 centimetres is designated by ∞.

Substance.	Temp. °C.	Wave-length cm.	Dial. constant.	Authority.	Substance.	Temp. °C.	Wave-length cm.	Dial. constant.	Authority.
Air	−191	∞	1.432	1	Nitrous oxide N_2O	−88	∞	1.938	8
"	"	75	1.47–1.50	2	" "	−5	"	1.630	5
Ammonia	−34	75	21–23	3	" "	+5	"	1.578	5
"	14	130	16.2	4	" "	+15	"	1.520	5
Carbon dioxide	−5	∞	1.608	5	Oxygen	−182	"	1.491	9
" "	0	"	1.588	"	"	"	"	1.468	9
" "	+10	"	1.540	"	Sulphur dioxide	14.5	120	13.75	4
" "	+15	"	1.526	"	" "	20	∞	14.0	6
Chlorine	−60	"	2.150	"	" "	40	"	12.5	"
"	−20	"	2.030	"	" "	60	"	10.8	"
"	0	"	1.970	"	" "	80	"	9.2	"
"	+10	"	1.940	"	" "	100	"	7.8	"
"	0	"	2.08	6	" "	120	"	6.4	"
"	+14	100	1.88	4	" "	140	"	4.8	"
Cyanogen	23	84	2.52	7	Critical	154.2	"	2.1	"
Hydrocyanic acid	21	"	about 95	"					
Hydrogen sulph.	10	∞	5.93	6					
" "	50	"	4.92	"					
" "	90	"	3.76	"					

1 v. Pirani, 1903.
2 Bahn-Kiebitz, 1904.
3 Goodwin-Thompson, 1899.
4 Coolidge, 1899.
5 Linde, 1895.
6 Eversheim, 1904.
7 Schlundt, 1901.
8 Hasenöhrl, 1900.
9 Fleming-Dewar, 1896.

TABLE 292.—Standard Solutions for the Calibration of Apparatus for the Measuring of Dielectric Constants.

Turner.		Drude.				Nernst.	
Substance.	Diel. const. at 18°. $\lambda = \infty$.	Acetone in benzol at 19°. $\lambda = 75$ cm.				Ethyl alcohol in water at 19.5°. $\lambda = \infty$.	
		Per cent by weight.	Density 16°.	Dielectric constant.	Temp. coefficient.	Per cent by weight.	Dielectric constant.
Benzol	2.288	0	0.885	2.26	0.1%	100	26.0
Meta-xylol	2.376	20	0.866	5.10	0.3	90	29.3
Ethyl ether	4.36[7]	40	0.847	8.43	0.4	80	33.5
Aniline	7.29[8]	60	0.830	12.1	0.5	70	38.0
Ethyl chloride	10.90	80	0.813	16.2	0.5	60	43.1
O-nitro toluol	27.71	100	0.797	20.5	0.6		
Nitrobenzol	36.45	Water in acetone at 19°. $\lambda = 75$ cm.					
Water (conduct. 10^{-6})	81.07	0	0.797	20.5	0.6%		
		20	0.856	31.5	0.5		
		40	0.903	43.5	0.5		
		60	0.940	57.0	0.5		
		80	0.973	70.6	0.		
		100	0.999	80.9	0.4		

TABLE 293.—Dielectric Constants of Solids.

Substance.	Condition.	Wave-length, cm.	Dielectric constant.	Authority.	Substance.	Condition.	Wave-length, cm.	Dielectric constant.	Authority.
Asphalt	–	∞	2.68	1		Temp.			
Barium sulphate	–	75	10.2	2	Iodine (cryst.)	23	75	4.00	2
Caoutchouc	–	∞	2.22	3	Lead chloride				
Diamond	–	"	16.5	1	(powder)	–	"	42	2
"	–	75	5.50	2	" nitrate	–	"	16	2
Ebonite	–	∞	2.72	4	" sulphate	–	"	28	2
"	–	"	2.86	5	" molybdenate	–	"	24	2
"	–	1000	2.55	6	Marble (Carrara)	–	"	8.3	2
Glass *	Density.				Mica	–	∞	5.66–5.97	5
Flint (extra heavy)	4.5	∞	9.90	7	"	–	"	5.80–6.62	15
Flint (very light)	2.87	"	6.61	7	Madras, brown	–	"	2.5–3.4	16
Hard crown	2.48	"	6.96	7	" green	–	"	3.9–5.5	16
Mirror	–	"	6.44–7.46	5	" ruby	–	"	4.4	16
"	–	"	5.37–5.90	8	Bengal, yellow	–	"	2.8	16
"	–	600	5.42–6.20	8	" white	–	"	4.2	16
Lead (Powell)	3.0–3.5	∞	5.4–8.0	9	" ruby	–	"	4.2–4.7	16
Jena					Canadian amber	–	"	3.0	16
Boron	–	"	5.5–8.1	10	South America	–	"	5.9	16
Barium	–	"	7.8–8.5	10	Ozokerite (raw)	–	"	2.21	1
Borosilicate	–	"	6.4–7.7	1	Paper (telephone)	–	"	2.0	17
Gutta percha	–	–	3.3–4.9	11	" (cable)	–	"	2.0–2.5	1
	Temp.				Paraffine	Melting point.	"	2.46	18
Ice	–5	1200	2.85	12	"	"	"	2.32	19
"	–18	5000	3.16	13	"	44–46	"	2.10	20
"	–190	75	1.76–1.88	14	"	54–56	"	2.14	20
					"	74–76	"	2.16	20

References on p. 284.

* For the effect of temperature, see Gray-Dobbie, Pr. Roy. Soc. 63, 1898; 67, 1900.
" " " " wave-length, see K. F. Löwe, Wied. Ann. 66, 1898.

DIELECTRIC CONSTANTS (*continued*).

TABLE 293.—Dielectric Constants of Solids (*continued*).

Substance.	Condition.	Wavelength, cm.	Diel. constant.	Authority.
Paraffine	47.°6	61	2.16	21
"	56.°2	61	2.25	21
Phosphorus:				
Yellow	–	75	3.60	2
Solid	–	80	4.1	22
Liquid	–	80	3.85	22
Porcelain:				
Hard (Royal B'l'n)	–	∞	5.73	15
Seger " "	–	"	6.61	15
Figure " "	–	"	6.84	15
Selenium	–	"	7.44	1
"	–	75	6.60	2
"	–	∞	6.13	23
"	–	1000	6.14	23
Shellac	–	∞	3.10	4
"	–	"	2.95–3.73	24
"	–	"	3.67	25
Sulphur				
Amorphous	–	∞	3.98	1
"	–	75	3.80	2
Cast, fresh	–	∞	4.22	1
" "	–	"	4.05	18
" "	–	75	3.95	2
Cast, old	–	∞	3.60	18
" "	–	75	3.90	2
Liquid	near melting-point	∞	3.42	1
Strontium sulphate	–	75	11.3	2
Thallium carbonate	–	75	17	2
" nitrate	–	75	16.5	2
Wood			dried	
Red beech	∥ fibres	∞	4.83–2.51	–
" "	⊥ "	"	7.73–3.63	–
Oak	∥ "	"	4.22–2.46	–
"	⊥ "	"	6.84–3.64	–

1 v. Pirani, 1903.
2 Schmidt, 1903.
3 Gordon, 1879.
4 Winklemann, 1889.
5 Elsas, 1891.
6 Ferry, 1897.
7 Hopkinson, 1891.
8 Arons-Rubens, 1891.
9 Gray-Dobbie, 1898.
10 Löwe, 1898.
11 (submarine-data).
12 Thwing, 1894.
13 Abegg, 1897.
14 Behn-Kiebitz, 1904.
15 Starke, 1897.
16 E. Wilson.
17 Campbell, 1906.
18 Fallinger, 1902.
19 Boltzmann, 1875.
20 Zietkowski, 1900.
21 Hormell, 1902.
22 Schlundt, 1904.
23 Vonwiller-Mason, 1907.
24 Wüllner, 1887.
25 Donle.

TABLE 294.—Dielectric Constants of Crystals.

Dα, Dβ, Dγ are the dielectric constants along the brachy, macro and vertical axes respectively.

Substance.	Wavelength, cm.	Diel. const. ⊥ Axis.	Diel. const. ∥ Axis.	Authority.
UNIAXIAL:				
Apatite	75	9.50	7.40	1
Beryl	∞	7.85	7.44	2
"	"	7.10	6.05	3
"	75	6.05	5.52	1
Calcspar	∞	8.49	7.56	4
"	"	8.78	8.29	5
Dolomite	75	7.80	6.80	1
Iceland spar	75	8.50	8.00	1
Quartz	∞	4.69	5.06	4
"	"	4.38	4.46	6
"	1000	4.27	4.34	6
"	75	4.32	4.60	1
Rutil (TiO_2)	75	89	173	1
Tourmaline	∞	7.13	6.54	4
"	75	6.75	5.65	1
Zircon	75	12.8	12.6	1

Substance.	Wavelength, cm.	Diel. const. Dα	Dβ	Dγ	Authority.
RHOMBIC:					
Arragonite	∞	9.14	–	7.13	4
"	75	9.80	7.68	6.55	1
Barite	∞	6.97	10.09	7.00	4
"	75	7.65	12.20	7.70	1
Cœlestin	75	7.70	18.5	8.30	1
Cerussite	75	25.4	23.2	19.2	1
$MgSO_4 + 7H_2O$	∞	5.26	6.05	8.28	7
K_2SO_4	"	6.09	5.08	4.48	7
Rochelle salt	"	6.70	6.92	8.89	7
Sulphur	"	3.81	3.97	4.77	8
"	"	3.65	3.85	4.66	7
"	75	3.62	3.85	4.66	1
Topaz	75	6.65	6.70	6.30	1

1 Schmidt, 1903.
2 Starke, 1897.
3 Curie, 1889.
4 Fallinger, 1902.
5 v. Pirani, 1903.
6 Ferry, 1897.
7 Borel, 1893.
8 Boltzmann, 1875.

VARIATION OF ELECTRICAL RESISTANCE OF GLASS AND PORCELAIN WITH TEMPERATURE.

The following table gives the values of a, b, and c in the equation

$$\log R = a + bt + ct^2,$$

where R is the specific resistance expressed in ohms, that is, the resistance in ohms per centimetre of a rod one square centimetre in cross section.*

No.	Kind of glass.	Density.	a	b	c	Range of temp. Centigrade.
1	Test-tube glass	–	13.86	—.044	.000065	0°–250°
2	" " "	2.458	14.24	—.055	.0001	37–131
3	Bohemian glass	2.43	16.21	—.043	.0000394	60–174
4	Lime glass (Japanese manufacture)	2.55	13.14	—.031	—.000021	10–85
5	" " " "	2.499	14.002	—.025	—.00006	35–95
6	Soda-lime glass (French flask)	2.533	14.58	—.049	.000075	45–120
7	Potash-soda lime glass	2.58	16.34	—.0425	.0000364	66–193
8	Arsenic enamel flint glass	3.07	18.17	—.055	.000088	105–135
9	Flint glass (Thomson's electrometer jar)	3.172	18.021	—.036	—.0000091	100–200
10	Porcelain (white evaporating dish)	–	15.65	—.042	.00005	68–290

COMPOSITION OF SOME OF THE ABOVE SPECIMENS OF GLASS.

Number of specimen =	3	4	5	7	8	9
Silica	61.3	57.2	70.05	75.65	54.2	55.18
Potash	22.9	21.1	1.44	7.92	10.5	13.28
Soda	Lime, etc.	Lime, etc.	14.32	6.92	7.0	–
Lead oxide	by diff.	by diff.	2.70	–	23.9	31.01
Lime	15.8	16.7	10.33	8.48	0.3	0.35
Magnesia	–	–	–	0.36	0.2	0.06
Arsenic oxide	–	–	–	–	3.5	–
Alumina, iron oxide, etc.	–	–	1.45	0.70	0.4	0.67

* T. Gray, "Phil. Mag." 1880, and "Proc. Roy. Soc." 1882.

PERMEABILITY OF IRON.

TABLE 296.—Permeability of Iron Rings and Wire.

This table gives, for a few specimens of iron, the magnetic induction B, and permeability μ, corresponding to the magneto-motive forces H recorded in the first column. The first specimen is taken from a paper by Rowland,* and refers to a welded and annealed ring of "Burden's Best" wrought iron. The ring was 6.77 cms. in mean diameter, and the bar had a cross sectional area of 0.916 sq. cms. Specimens 2-4 are taken from a paper by Bosanquet,† and also refers to soft iron rings. The mean diameters were 21.5, 22.1, and 22.725 cms., and the thickness of the bars 2.535, 1.295, and .7544 cms. respectively. These experiments were intended to illustrate the effect of thickness of bar on the induction. Specimen 5 is from Ewing's book,‡ and refers to one of his own experiments on a soft iron wire .077 cms. diameter and 30.5 cms. long.

H	Specimen 1		2		3		4		5		Note.—The comparatively high value of the magnetizing force required for maximum permeability when the specimen is a thin drawn wire is noticeable in specimen 5.
	B	μ	B	μ	B	μ	B	μ	B	μ	
0.2	80	400	126	630	65	325	85	425	22	110	
0.5	330	660	377	754	224	448	214	428	74	148	
1.0	1450	1450	1449	1449	840	840	885	885	246	246	
2.0	4840	2420	4564	2282	3533	1766	2417	1208	950	475	
5.0	9880	1976	9900	1980	8293	1659	8884	1777	12430	2486	
10.0	12970	1297	13023	1302	12540	1254	11388	1139	15020	1502	
20.0	14740	737	14911	746	14710	735	13273	664	15790	789	
50.0	16390	328	16217	324	16062	321	13890	278	–	–	
100.0	–	–	17148	171	17900	179	14837	148	–	–	

TABLE 297.—Permeability of Transformer Iron.§

This table contains the results of some experiments on transformers of the Westinghouse and Thomson-Houston types. Referring to the headings of the different columns, M is the total magneto-motive force applied to the iron; M/l the magneto-motive force per centimetre length of the iron circuit; B the total induction through the magnetizing coil; B/a the induction per square centimetre of the mean section of the iron core; M/B the magnetic reluctance of the iron circuit; Bl/Ma the permeability of the iron, a being taken as the mean cross section of the iron circuit as it exists in the transformer, which is thus slightly greater than the actual cross section of the iron.

(a) WESTINGHOUSE NO. 8 TRANSFORMERS (ABOUT 2500 WATTS CAPACITY).

M	$\frac{M}{l}$	First specimen.				Second specimen.			
		B	$\frac{B}{a}$	$\frac{M}{B}$	$\frac{Bl}{Ma}$	B	$\frac{B}{a}$	$\frac{M}{B}$	$\frac{Bl}{Ma}$
20	0.597	218×10^3	1406	0.917×10^{-4}	2360	16×10^4	1032	1.25×10^{-4}	1730
40	1.194	587 "	3790	0.681 "	3120	49 "	3140	0.82 "	2640
60	1.791	878 "	5660	0.683 "	3180	82 "	5290	0.73 "	2970
80	2.338	1091 "	7040	0.734 "	2960	104 "	6710	0.77 "	2820
100	2.985	1219 "	7860	0.819 "	2640	118 "	7610	0.85 "	2560
120	3.582	1330 "	8580	0.903 "	2410	124 "	8000	0.97 "	2250
140	4.179	1405 "	9060	0.994 "	2186	131 "	8450	1.07 "	2036
160	4.776	1475 "	9510	1.090 "	2000	135 "	8710	1.18 "	1830
180	5.373	1532 "	9880	1.180 "	1850	140 "	9030	1.29 "	1690
200	5.970	1581 "	10200	1.270 "	1720	142 "	9160	1.41 "	1540
220	6.567	1618 "	10430	1.360 "	1590	144 "	9290	1.53 "	1410
260	7.761	1692 "	10910	1.540 "	1410	–	–	–	–

* "Phil. Mag." 4th series, vol. xlv. p. 151.
† Ibid. 5th series, vol. xix. p. 73.
‡ "Magnetic Induction in Iron and Other Metals."
§ T. Gray, from special experiments.

PERMEABILITY OF TRANSFORMER IRON.

(b) WESTINGHOUSE No. 6 TRANSFORMERS (ABOUT 1800 WATTS CAPACITY).

M	$\frac{M}{l}$	First specimen. B	$\frac{B}{a}$	$\frac{M}{B}$	$\frac{Bl}{Ma}$	Second specimen. B	$\frac{B}{a}$	$\frac{M}{B}$	$\frac{Bl}{Ma}$
20	0.62	147×10^3	1320	1.36×10^{-4}	2140	215×10^3	1940	0.93×10^{-4}	3140
40	1.23	442 "	3980	0.91 "	3260	615 "	5540	0.64 "	4490
60	1.85	697 "	6280	0.86 "	3390	826 "	7440	0.72 "	4030
80	2.46	862 "	7770	0.93 "	3140	986 "	8880	0.81 "	3590
100	3.08	949 "	8550	1.05 "	2770	1050 "	9460	0.95 "	3060
120	3.70	1010 "	9106	1.19 "	2450	1100 "	9910	1.09 "	2670
140	4.31	1060 "	9550	1.33 "	2210	1140 "	10300	1.23 "	2430
160	4.93	1090 "	9820	1.47 "	1990	1170 "	10500	1.37 "	2180
180	5.55	1120 "	10100	1.61 "	1830	1190 "	10700	1.51 "	1970
200	6.16	1150 "	10400	1.74 "	1680	–	–	–	–

(c) WESTINGHOUSE No. 4 TRANSFORMER (ABOUT 1200 WATTS CAPACITY).

M	$\frac{M}{l}$	B	$\frac{B}{a}$	$\frac{M}{B}$	$\frac{Bl}{Ma}$
20	0.69	147×10^3	1470	1.36×10^{-4}	2140
40	1.38	406 "	4066	0.98 "	2940
60	2.07	573 "	5730	1.05 "	2770
80	2.76	659 "	6590	1.21 "	2390
100	3.45	714 "	7140	1.40 "	2070
120	4.14	748 "	7490	1.60 "	1810
140	4.83	777 "	7770	1.80 "	1610

(d) THOMSON-HOUSTON 1500 WATTS TRANSFORMER.

M	$\frac{M}{l}$	B	$\frac{B}{a}$	$\frac{M}{B}$	$\frac{Bl}{Ma}$
20	0.42	70×10^3	1560	2.86×10^{-4}	3730
40	0.84	142 "	3160	2.81 "	3780
60	1.26	214 "	4770	2.81 "	3790
80	1.68	265 "	5910	3.02 "	3520
100	2.10	309 "	6890	3.24 "	3280
120	2.52	348 "	7760	3.45 "	3080
160	3.36	408 "	9100	3.92 "	2710
200	4.20	456 "	10200	4.39 "	2430
240	5.04	495 "	11000	4.87 "	2190
280	5.88	524 "	11690	5.35 "	1990
320	6.72	550 "	12270	5.82 "	1820
360	7.56	573 "	12780	6.29 "	1690
400	8.40	591 "	13180	6.78 "	1570
440	9.24	504 "	13470	7.28 "	1460

TABLE 298. — Magnetic Properties of Iron and Steel.

	Electrolytic Iron.	Good Cast Steel.	Poor Cast Steel.	Steel.	Cast Iron.	Electrical Sheets.	
						Ordinary.	Silicon Steel.
Chemical composition in per cent C	0.024	0.044	0.56	0.99	3.11	0.036	0.036
Si	0.004	0.004	0.18	0.10	3.27	0.330	3.90
Mn	0.008	0.40	0.29	0.40	0.56	0.260	0.090
P	0.008	0.044	0.076	0.04	1.05	0.040	0.009
S	0.001	0.027	0.035	0.07	0.06	0.068	0.006
Coercive force	2.83	1.51	7.1	16.7	11.4		
	[0.36]	[0.37]	(44.3)	(52.4)	[4.6]	[1.30]	[0.77]
Residual B	11400	10600	10500	13000	5100		
	[10800]	[11000]	(10500)	(7500)	[5350]	[9400]	[9850]
Maximum permeability	1850	3550	700	375	240		
	[14400]	[14800]	(170)	(110)	[600]	[3270]	[6130]
B for H=150	19200	18800	17400	16700	10400		
	[18900]	[19100]	(15400)	(11700)	[11000]	[18200]	[17550]
$4\pi I$ for saturation	21620	21420	20600	19800	16400		
	[21630]	[21420]	(20200)	(18000)	[16800]	[20500]	[19260]

E. Gumlich, Zs. für Electrochemie, 15, p. 599; 1909.

Brackets indicate annealing at 800° C in vacuum. *Parentheses* indicate hardening by quenching from cherry-red.

TABLE 299. — Cast Iron in Intense Fields.

Soft Cast Iron.				Hard Cast Iron.			
H	B	I	μ	H	B	I	μ
114	9950	782	87.3	142	7860	614	55.4
172	10800	846	62.8	254	9700	752	38.2
433	13900	1070	32.1	339	10850	836	30.6
744	15750	1200	21.2	684	13050	983	19.1
1234	17300	1280	14.0	915	14050	1044	15.4
1820	18170	1300	10.0	1570	15900	1138	10.1
12700	31100	1465	2.5	2020	16800	1146	8.3
13550	32100	1475	2.4	10900	26540	1235	2.4
13800	32500	1488	2.4	13200	28600	1226	2.2
15100	33650	1472	2.2	14800	30200	1226	2.0

B. O. Peirce, Proc. Am. Acad. 44, 1909.

TABLE 300. — Corrections for Ring Specimens.

In the case of ring specimens, the average magnetizing force is not the value at the mean radius, the ratio of the two being given in the table. The flux density consequently is not uniform, and the measured hysteresis is less than it would be for a uniform distribution. This ratio is also given for the case of constant permeability, the values being applicable for magnetizations in the neighborhood of the maximum permeability. For higher magnetizations the flux density is more uniform, for lower it is less, and the correction greater.

Ratio of Radial Width to Diameter of Ring.	Ratio of Average H to H at Mean Radius.		Ratio of Hysteresis for Uniform Distribution to Actual Hysteresis.	
	Rectangular Cross-section.	Circular Cross-section.	Rectangular Cross-section.	Circular Cross-section.
1/2	1.0986	1.0718	1.112	1.084
1/3	1.0397	1.0294	1.045	1.033
1/4	1.0216	1.0162	1.024	1.018
1/5	1.0137	1.0102	1.015	1.011
1/6	1.0094	1.0070	1.010	1.008
1/7	1.0069	1.0052	1.008	1.006
1/8	1.0052	1.0040	1.006	1.004
1/10	1.0033	1.0025	1.003	1.002
1/19	1.0009	1.0007	1.001	1.001

M. G. Lloyd, Bull. Bur. Standards, 5, p. 435; 1908.

DEMAGNETIZING FACTORS FOR RODS.

TABLE 301.

H = true intensity o. magnetizing field, H' = intensity of applied field, I = intensity of magnetization, $H = H' - NI$.

Shuddemagen says: The demagnetizing factor is not a constant, falling for highest values of I to about 1/7 the value when unsaturated; for values of B $(= H + 4\pi I)$ less than 10000, N is approximately constant; using a solenoid wound on an insulating tube, or a tube of split brass, the reversal method gives values for N which are considerably lower than those given by the step-by-step method; if the solenoid is wound on a thick brass tube, the two methods practically agree.

Ratio of Length to Diameter.	Values of $N \times 10^4$.						
	Ellipsoid.	Cylinder.					
		Uniform Magnetization.	Magnetometric Method (Mann).	Ballistic Step Method.			
				Dubois.	Shuddemagen for Range of Practical Constancy.		
				Diameter.			
				0.158 cm.	0.3175 cm.	1.111 cm.	1.905 cm.
5	7015	–	6800				
10	2549	630	2550	2160	–	–	1960
15	1350	280	1400	1206	–	–	1075
20	848	160	898	775	–	–	671
30	432	70	460	393	388	350	343
40	266	39	274	238	234	212	209
50	181	25	182	162	160	145	149
60	132	18	131	118	116	106	106
70	101	13	99	89	88		
80	80	9.8	78	69	69	66	63
90	65	7.8	63	55	56		
100	54	6.3	51.8	45	46	41	41
150	26	2.8	25.1	20	23	21	21
200	16	1.57	15.2	11	12.5	11	11
300	7.5	0.70	7.5	5.0			
400	4.5	0.39	–	2.8			

C. R. Mann, Physical Review, 3, p. 359; 1896.
H. DuBois, Wied. Ann. 7, p. 942; 1902.
C. L. B. Shuddemagen, Proc. Am. Acad. Arts and Sci. 43, p. 185, 1907 (Bibliography).

TABLE 302.

Shuddemagen also gives the following, where B is determined by the step method and $H = H' - KB$.

Ratio of Length to Diameter.	Values of $K \times 10^4$.	
	Diameter 0.3175 cm.	Diameter 1.1 to 2.0 cm.
15	–	85.2
20	–	53.3
25	–	36.6
30	30.9	27.3
40	18.6	16.6
50	12.7	11.6
60	9.25	8.45
80	5.5	5.05
100	3.66	3.26
150	1.83	1.67

COMPOSITION AND MAGNETIC

This table and Table 289 below are taken from a paper by Dr. Hopkinson * on the magnetic properties of iron and steel which is stated in the paper to have been 240. The maximum magnetization is not tabulated; but as stated in the by 4π. "Coercive force" is the magnetizing force required to reduce the magnetization to zero. The "demag previous magnetization in the opposite direction to the "maximum induction" stated in the table. The "energy which, however, was only found to agree roughly with the results of experiment.

No. of Test.	Description of specimen.	Temper.	Chemical analysis.					
			Total Carbon.	Manganese.	Sulphur.	Silicon.	Phosphorus.	Other substances.
1	Wrought iron	Annealed	–	–	–	–	–	–
2	Malleable cast iron	"	–	–	–	–	–	–
3	Gray cast iron	–	–	–	–	–	–	–
4	Bessemer steel	–	0.045	0.200	0.030	None.	0.040	–
5	Whitworth mild steel	Annealed	0.090	0.153	0.016	"	0.042	–
6	" "	"	0.320	0.438	0.017	0.042	0.035	–
7	" "	Oil-hardened	"	"	"	"	"	–
8	" "	Annealed	0.890	0.165	0.005	0.081	0.019	–
9	" "	Oil-hardened	"	"	"	"	"	–
10	Hadfield's manganese steel	–	1.005	12.360	0.038	0.204	0.070	–
11	Manganese steel	As forged	0.674	4.730	0.023	0.608	0.078	–
12	" "	Annealed	"	"	"	"	"	–
13	" "	Oil-hardened	"	"	"	"	"	–
14	" "	As forged	1.298	8.740	0.024	0.094	0.072	–
15	" "	Annealed	"	"	"	"	"	
16	" "	Oil-hardened	"	"	"	"	"	–
17	Silicon steel	As forged	0.685	0.694	"	3.438	0.123	–
18	" "	Annealed	"	"	"	"	"	–
19	" "	Oil-hardened	"	"	"	"	"	–
20	Chrome steel	As forged	0.532	0.393	0.020	0.220	0.041	0.621 Cr.
21	" "	Annealed	"	"	"	"	"	"
22	" "	Oil-hardened	"	"	"	"	"	"
23	" "	As forged	0.687	0.028	"	0.134	0.043	1.195 Cr.
24	" "	Annealed	"	"	"	"	"	"
25	" "	Oil-hardened	"	"	"	"	"	"
26	Tungsten steel	As forged	1.357	0.036	None.	0.043	0.047	4.649 W.
27	" "	Annealed	"	"	"	"	"	"
28	" "	Hardened in cold water	"	"	"	"	"	"
29	" "	Hardened in tepid water	"	"	"	"	"	"
30	" " (French)	Oil-hardened	0.511	0.625	None.	0.021	0.028	3.444 W.
31	" "	Very hard	0.855	0.312	–	0.151	0.089	2.353 W.
32	Gray cast iron	–	3.455	0.173	0.042	2.044	0.151	2.004 C.†
33	Mottled cast iron	–	2.581	0.610	0.105	1.476	0.435	1.477 C.†
34	White " "	–	2.036	0.386	0.467	0.764	0.458	–
35	Spiegeleisen	–	4.510	7.970	Trace.	0.502	0.128	–

* Phil. Trans. Roy. Soc. vol. 176.

† Graphitic carbon.

PROPERTIES OF IRON AND STEEL.

The numbers in the columns headed "magnetic properties" give the results for the highest magnetizing force used, paper, it may be obtained by subtracting the magnetizing force (240) from the maximum induction and then dividing netizing force" is the magnetizing force which had to be applied in order to leave no residual magnetization after dissipated" was calculated from the formula:— Energy dissipated = coercive force × maximum induction ÷ π

No. of Test.	Description of specimen.	Temper.	Specific electrical resistance.	Magnetic properties.				Energy dissipated per cycle.
				Maximum induction.	Residual induction.	Coercive force.	Demagnetizive force.	
1	Wrought iron	Annealed	.01378	18251	7248	2.30	–	13356
2	Malleable cast iron	"	.03254	12408	7479	8.80	–	34742
3	Gray cast iron	–	.10560	10783	3928	3.80	–	13037
4	Bessemer steel	–	.01050	18196	7860	2.96	–	17137
5	Whitworth mild steel	Annealed	.01080	19840	7080	1.63	–	10289
6	" "	"	.01446	18736	9840	6.73	–	40120
7	" "	Oil-hardened	.01390	18796	11040	11.00	–	65786
8	" "	Annealed	.01559	16120	10740	8.26	–	42366
9	" "	Oil-hardened	.01695	16120	8736	19.38	–	99401
10	Hadfield's manganese steel	–	.06554	310	–	–		–
11	Manganese steel	As forged	.05368	4623	2202	23.50	37.13	34567
12	" "	Annealed	.03928	10578	5848	33.86	46.10	113963
13	" "	Oil-hardened	.05556	4769	2158	27.64	40.29	41941
14	" "	As forged	.06993	747	–	–	–	–
15	" "	Annealed	.06316	1985	540	24.50	50.39	15474
16	" "	Oil-hardened	.07066	733	–	–	–	–
17	Silicon steel	As forged	.06163	15148	11073	9.49	12.60	45740
18	" "	Annealed	.06185	14701	8149	7.80	10.74	36485
19	" "	Oil-hardened	.06195	14696	8084	12.75	17.14	59619
20	Chrome steel	As forged	.02016	15778	9318	12.24	13.87	61439
21	" "	Annealed	.01942	14848	7570	8.98	12.24	42425
22	" "	Oil-hardened	.02708	13960	8595	38.15	48.45	169455
23	" "	As forged	.01791	14680	7568	18.40	22.03	85944
24	" "	Annealed	.01849	13233	6489	15.40	19.79	64842
25	" "	Oil-hardened	.03035	12868	7891	40.80	56.70	167050
26	Tungsten steel	As forged	.02249	15718	10144	15.71	17.75	78568
27	" "	Annealed	.02250	16498	11008	15.30	16.93	80315
28	" "	Hardened in cold water	.02274	–	–	–	–	–
29	" "	Hardened in tepid water	.02249	15610	9482	30.10	34.70	149500
30	" " (French)	Oil hardened	.03604	14480	8643	47.07	64.46	216864
31	" "	Very hard	.04427	12133	6818	51.20	70.69	197660
32	Gray cast iron	–	.11400	9148	3161	13.67	17.03	39789
33	Mottled cast iron	–	.06286	10546	5108	12.24	–	41072
34	White " "	–	.05661	9342	5554	12.24	20.40	36383
35	Spiegeleisen	–	.10520	385	77	–	–	–

DIELECTRIC CONSTANTS OF LIQUIDS (*continued*).

TABLE 290.—Temperature Coefficients of the Formula:

$$D_\theta = D_t[1-\alpha(t-\theta)+\beta(t-\theta)^2].$$

Substance.	α	β	Temp. range, °C.	Authority.
Amyl acetate	0.0024	–	–	Löwe.
Aniline	0.00351	–	–	Ratz.
Benzol	0.00106	0.0000087	10–40	Hasenöhrl.
Carbon bisulphide	0.000966	–	–	Ratz.
" "	0.000922	0.00000060	20–181	Tangl.
Chloroform	0.00410	0.000015	22–181	"
Ethyl ether	0.00459	–	–	Ratz.
Methyl alcohol	0.0057	–	–	Drude.
Oils: Almond	0.00163	0.000026	–	Hasenöhrl.
Castor	0.01067	–	–	Heinke, 1896.
Olive	0.00364	–	–	" "
Paraffine	0.000738	0.0000072	–	Hasenöhrl.
Toluol	0.000921	–	0–13	Ratz.
"	0.000977	0.00000046	20–181	Tangl.
Water	0.004474	–	5–20	Heerwagen.
"	0.004583	0.0000117	0–76	Drude.
"	0.00436	–	4–25	Coolidge.
Meta-xylol	0.000817	–	20–181	Tangl.

(See Table 287 for the signification of the letters.)

TABLE 291.—Dielectric Constants of Liquified Gases.

A wave-length greater than 10000 centimetres is designated by ∞.

Substance.	Temp. °C.	Wave-length cm.	Dial. constant.	Authority.
Air	−191	∞	1.432	1
"	"	75	1.47–1.50	2
Ammonia	−34	75	21–23	3
"	14	130	16.2	4
Carbon dioxide	−5	∞	1.608	5
" "	0	"	1.588	"
" "	+10	"	1.540	"
" "	+15	"	1.526	"
Chlorine	−60	"	2.150	"
"	−20	"	2.030	"
"	0	"	1.970	"
"	+10	"	1.940	"
"	0	"	2.08	6
"	+14	100	1.88	4
Cyanogen	23	84	2.52	7
Hydrocyanic acid	21	"	about 95	"
Hydrogen sulph.	10	∞	5.93	6
" "	50	"	4.92	"
" "	90	"	3.76	"
Nitrous oxide N_2O	−88	∞	1.938	8
" "	−5	"	1.630	5
" "	+5	"	1.578	"
" "	+15	"	1.520	"
Oxygen	−182	"	1.491	"
"	"	"	1.468	"
Sulphur dioxide	14.5	120	13.75	4
" "	20	∞	14.0	6
" "	40	"	12.5	"
" "	60	"	10.8	"
" "	80	"	9.2	"
" "	100	"	7.8	"
" "	120	"	6.4	"
" "	140	"	4.8	"
Critical	154.2	"	2.1	"

1 v. Pirani, 1903.
2 Bahn-Kiebitz, 1904.
3 Goodwin-Thompson, 1899.
4 Coolidge, 1899.
5 Linde, 1895.
6 Eversheim, 1904.
7 Schlundt, 1901.
8 Hasenöhrl, 1900.
9 Fleming-Dewar, 1896.

TABLE 292.—Standard Solutions for the Calibration of Apparatus for the Measuring of Dielectric Constants.

Turner.		Drude.				Nernst.	
Substance.	Diel. const. at 18°. $\lambda = \infty$.	Acetone in benzol at 19°. $\lambda = 75$ cm.				Ethyl alcohol in water at 19.5°. $\lambda = \infty$.	
		Per cent by weight.	Density 16°.	Dielectric constant.	Temp. coefficient.	Per cent by weight.	Dielectric constant.
Benzol	2.288	0	0.885	2.26	0.1%	100	26.0
Meta-xylol	2.376	20	0.866	5.10	0.3	90	29.3
Ethyl ether	4.367	40	0.847	8.43	0.4	80	33.5
Aniline	7.298	60	0.830	12.1	0.5	70	38.0
Ethyl chloride	10.90	80	0.813	16.2	0.5	60	43.1
O-nitro toluol	27.71	100	0.797	20.5	0.6		
Nitrobenzol	36.45	Water in acetone at 19°. $\lambda = 75$ cm.					
Water (conduct. 10^{-6})	81.07	0	0.797	20.5	0.6%		
		20	0.856	31.5	0.5		
		40	0.903	43.5	0.5		
		60	0.940	57.0	0.5		
		80	0.973	70.6	0.		
		100	0.999	80.9	0.4		

TABLE 293.—Dielectric Constants of Solids.

Substance.	Condition.	Wave-length, cm.	Dielectric constant.	Authority.	Substance.	Condition.	Wave-length, cm.	Dielectric constant.	Authority.
Asphalt	–	∞	2.68	1		Temp.			
Barium sulphate	–	75	10.2	2	Iodine (cryst.)	23	75	4.00	2
Caoutchouc	–	∞	2.22	3	Lead chloride				
Diamond	–	"	16.5	1	(powder)	–	"	42	2
"	–	75	5.50	2	" nitrate	–	"	16	2
Ebonite	–	∞	2.72	4	" sulphate	–	"	28	2
"	–	"	2.86	5	" molybdenate	–	"	24	2
"	–	1000	2.55	6	Marble (Carrara)	–	"	8.3	2
Glass *	Density.				Mica	–	∞	5.66–5.97	5
Flint (extra heavy)	4.5	∞	9.90	7	"	–	"	5.80–6.62	15
Flint (very light)	2.87	"	6.61	7	Madras, brown	–	"	2.5–3.4	16
Hard crown	2.48	"	6.96	7	" green	–	"	3.9–5.5	16
Mirror	–	"	6.44–7.46	5	" ruby	–	"	4.4	16
"	–	"	5.37–5.90	8	Bengal, yellow	–	"	2.8	16
"	–	600	5.42–6.20	8	" white	–	"	4.2	16
Lead (Powell)	3.0–3.5	∞	5.4–8.0	9	" ruby	–	"	4.2–4.7	16
Jena					Canadian amber	–	"	3.0	16
Boron	–	"	5.5–8.1	10	South America	–	"	5.9	16
Barium	–	"	7.8–8.5	10	Ozokerite (raw)	–	"	2.21	1
Borosilicate	–	"	6.4–7.7	1	Paper (telephone)	–	"	2.0	17
Gutta percha	–	–	3.3–4.9	11	" (cable)	–	"	2.0–2.5	1
	Temp.				Paraffine	Melting point.	"	2.46	18
Ice	–5	1200	2.85	12	"		"	2.32	19
"	–18	5000	3.16	13	"	44–46	"	2.10	20
"	–190	75	1.76–1.88	14	"	54–56	"	2.14	20
					"	74–76	"	2.16	20

References on p. 284.

* For the effect of temperature, see Gray-Dobbie, Pr. Roy. Soc. 63, 1898; 67, 1900.
" " " " wave-length, see K. F. Löwe, Wied. Ann. 66, 1898.

DIELECTRIC CONSTANTS (*continued*).

TABLE 293. — Dielectric Constants of Solids (*continued*).

Substance.	Condition.	Wavelength, cm.	Diel. constant.	Authority.
Paraffine	47.°6	61	2.16	21
"	56.°2	61	2.25	21
Phosphorus:				
Yellow	–	75	3.60	2
Solid	–	80	4.1	22
Liquid	–	80	3.85	22
Porcelain:				
Hard (Royal B'l'n)	–	∞	5.73	15
Seger " "	–	"	6.61	15
Figure " "	–	"	6.84	15
Selenium	–	"	7.44	1
"	–	75	6.60	2
"	–	∞	6.13	23
"	–	1000	6.14	23
Shellac	–	∞	3.10	4
"	–	"	2.95–3.73	24
"	–	"	3.67	25
Sulphur				
Amorphous	–	∞	3.98	1
"	–	75	3.80	2
Cast, fresh	–	∞	4.22	1
" "	–	"	4.05	18
" "	–	75	3.95	2
Cast, old	–	∞	3.60	18
" "	–	75	3.90	2
Liquid	near melting-point	∞	3.42	1
Strontium sulphate	–	75	11.3	2
Thallium carbonate	–	75	17	2
" nitrate	–	75	16.5 dried	2
Wood				
Red beech	∥ fibres	∞	4.83–2.51	–
" "	⊥ "	"	7.73–3.63	–
Oak	∥ "	"	4.22–2.46	–
"	⊥ "	"	6.84–3.64	–

1 v. Pirani, 1903.
2 Schmidt, 1903.
3 Gordon, 1879.
4 Winklemann, 1889.
5 Elsas, 1891.
6 Ferry, 1897.
7 Hopkinson, 1891.
8 Arons-Rubens, 1891.
9 Gray-Dobbie, 1898.
10 Löwe, 1898.
11 (submarine-data).
12 Thwing, 1894.
13 Abegg, 1897.
14 Behn-Kiebitz, 1904.
15 Starke, 1897.
16 E. Wilson.
17 Campbell, 1906.
18 Fallinger, 1902.
19 Boltzmann, 1875.
20 Zietkowski, 1900.
21 Hormell, 1902.
22 Schlundt, 1904.
23 Vonwiller-Mason, 1907.
24 Wüllner, 1887.
25 Donle.

TABLE 294. — Dielectric Constants of Crystals.

Dα, Dβ, Dγ are the dielectric constants along the brachy, macro and vertical axes respectively.

Substance.	Wavelength, cm.	Diel. const. ⊥ Axis.	Diel. const. ∥ Axis.	Authority.
UNIAXIAL:				
Apatite	75	9.50	7.40	1
Beryl	∞	7.85	7.44	2
"	"	7.10	6.05	3
"	75	6.05	5.52	1
Calcspar	∞	8.49	7.56	4
"	"	8.78	8.29	5
Dolomite	75	7.80	6.80	1
Iceland spar	75	8.50	8.00	1
Quartz	∞	4.69	5.06	4
"	"	4.38	4.46	6
"	1000	4.27	4.34	6
"	75	4.32	4.60	1
Rutil (TiO_2)	75	89	173	1
Tourmaline	∞	7.13	6.54	4
"	75	6.75	5.65	1
Zircon	75	12.8	12.6	1

Substance.	Wavelength, cm.	Diel. const. Dα	Dβ	Dγ	Authority.
RHOMBIC:					
Arragonite	∞	9.14	–	7.13	4
"	75	9.80	7.68	6.55	1
Barite	∞	6.97	10.09	7.00	4
"	75	7.65	12.20	7.70	1
Cœlestin	75	7.70	18.5	8.30	1
Cerussite	75	25.4	23.2	19.2	1
$MgSO_4 + 7H_2O$	∞	5.26	6.05	8.28	7
K_2SO_4	"	6.09	5.08	4.48	7
Rochelle salt	"	6.70	6.92	8.89	7
Sulphur	"	3.81	3.97	4.77	8
"	"	3.65	3.85	4.66	7
"	75	3.62	3.85	4.66	1
Topaz	75	6.65	6.70	6.30	1

1 Schmidt, 1903.
2 Starke, 1897.
3 Curie, 1889.
4 Fallinger, 1902.
5 v. Pirani, 1903.
6 Ferry, 1897.
7 Borel, 1893.
8 Boltzmann, 1875.

VARIATION OF ELECTRICAL RESISTANCE OF GLASS AND PORCELAIN WITH TEMPERATURE.

The following table gives the values of a, b, and c in the equation

$$\log R = a + bt + ct^2,$$

where R is the specific resistance expressed in ohms, that is, the resistance in ohms per centimetre of a rod one square centimetre in cross section.*

No.	Kind of glass.	Density.	a	b	c	Range of temp. Centigrade.
1	Test-tube glass	–	13.86	—.044	.000065	0°–250°
2	" " "	2.458	14.24	—.055	.0001	37–131
3	Bohemian glass	2.43	16.21	—.043	.0000394	60–174
4	Lime glass (Japanese manufacture)	2.55	13.14	—.031	—.000021	10–85
5	" " " "	2.499	14.002	—.025	—.00006	35–95
6	Soda-lime glass (French flask)	2.533	14.58	—.049	.000075	45–120
7	Potash-soda lime glass	2.58	16.34	—.0425	.0000364	66–193
8	Arsenic enamel flint glass	3.07	18.17	—.055	.000088	105–135
9	Flint glass (Thomson's electrometer jar)	3.172	18.021	—.036	—.0000091	100–200
10	Porcelain (white evaporating dish)	–	15.65	—.042	.00005	68–290

COMPOSITION OF SOME OF THE ABOVE SPECIMENS OF GLASS.

Number of specimen =	3	4	5	7	8	9
Silica	61.3	57.2	70.05	75.65	54.2	55.18
Potash	22.9	21.1	1.44	7.92	10.5	13.28
Soda	Lime, etc.	Lime, etc.	14.32	6.92	7.0	–
Lead oxide	by diff.	by diff.	2.70	–	23.9	31.01
Lime	15.8	16.7	10.33	8.48	0.3	0.35
Magnesia	–	–	–	0.36	0.2	0.06
Arsenic oxide	–	–	–	–	3.5	–
Alumina, iron oxide, etc.	–	–	1.45	0.70	0.4	0.67

* T. Gray, "Phil. Mag." 1880, and "Proc. Roy. Soc." 1882.

TABLE 318.

ENERGY LOSSES IN TRANSFORMER STEELS.

Determined by the wattmeter method.

Loss per cycle per $cc = AB^x + bnB^y$, where B = flux density in gausses and n = frequency in cycles per second. x shows the variation of hysteresis with B between 5000 and 10000 gausses, and y the same for eddy currents.

Designation.	Thickness. cm.	Ergs per Gramme per Cycle.				x	y	a	Watts per Pound at 60 Cycles and 10000 Gausses.		
		10000 Gausses.		5000 Gausses.							
		Hysteresis.	Eddy Currents at 60.	Hysteresis.	Eddy Currents at 60.				Eddy Current Loss for Gage No. 29. ‡	Hysteresis.	Total.
Unannealed											
A	0.0399	1599	186	562	46	1.51	2.02	0.00490	0.41	4.35	4.76
B	.0326	1156	134	384	36	1.59	1.89	.00358	0.44	3.14	3.58
C	.0422	1032	242	356	70	1.51	1.79	.00319	0.47	2.81	3.28
D	.0381	1009	184	353	48	1.52	1.94	.00312	0.44	2.74	3.18
Annealed											
E	.0476	735	236	246	58	1.58	2.02	.00227	0.36	2.00	2.36
F	.0280	666	100	220	27	1.60	1.88	.00206	0.44	1.81	2.25
G	.0394	563	210	193	54	1.54	1.96	.00174	0.47	1.53	2.00
H*	.0307	412	146	138.5	39	1.58	1.90	.00127	0.54	1.12	1.66
J	.0318	341	202	111.5	55	1.62	1.88	.00105	0.70	0.93	1.63
K*	.0282	394	124	130	32	1.61	1.90	.00122	0.54	1.07	1.61
L	.0346	381	184	125	50	1.61	1.88	.00118	0.535	1.035	1.57
B	.0338	354	200	116	57	1.61	1.81	.00110	0.61	0.96	1.57
M	.0335	372	178	127	46	1.55	1.95	.00115	0.55	1.01	1.56
N	.0340	321	210	105	56	1.62	1.90	.00099	0.63	0.87	1.50
P	.0437	334	184	107	50	1.64	1.88	.00103	0.34	0.91	1.25
Silicon steels											
Q†	.0361	303	54	98	15	1.63	–	.00094	0.14	0.825	0.965
R	.0315	288	42	93	11	1.64	–	.00089	0.15	0.78	0.93
S	.0452	278	72	90	18	1.63	–	.00086	0.12	0.755	0.875
T	.0338	250	60	78	18	1.68	–	.00077	0.18	0.68	0.86
U	.0346	270	42	86	12	1.66	–	.00084	0.12	0.735	0.855
V*	.0310	251.5	47	79	13	1.68	–	.00078	0.17	0.685	0.855
W*	.0305	197	43	62.3	12.4	1.67	–	.00061	0.16	0.535	0.695
X	.0430	200	65	64.2	16.6	1.65	–	.00062	0.12	0.545	0.665

* German. † English.

‡ In order to make a fair comparison, the eddy current loss has been computed for a thickness of 0.0357 cm. (Gage No. 29), assuming the loss proportional to the thickness.

Lloyd and Fisher, Bull. Bur. Standards, 5, p. 453; 1909.

PERMEABILITY OF TRANSFORMER IRON.

(b) WESTINGHOUSE No. 6 TRANSFORMERS (ABOUT 1800 WATTS CAPACITY).

M	$\frac{M}{l}$	First specimen. B	$\frac{B}{a}$	$\frac{M}{B}$	$\frac{Bl}{Ma}$	Second specimen. B	$\frac{B}{a}$	$\frac{M}{B}$	$\frac{Bl}{Ma}$
20	0.62	147×10^3	1320	1.36×10^{-4}	2140	215×10^3	1940	0.93×10^{-4}	3140
40	1.23	442 "	3980	0.91 "	3260	615 "	5540	0.64 "	4490
60	1.85	697 "	6280	0.86 "	3390	826 "	7440	0.72 "	4030
80	2.46	862 "	7770	0.93 "	3140	986 "	8880	0.81 "	3590
100	3.08	949 "	8550	1.05 "	2770	1050 "	9460	0.95 "	3060
120	3.70	1010 "	9106	1.19 "	2450	1100 "	9910	1.09 "	2670
140	4.31	1060 "	9550	1.33 "	2210	1140 "	10300	1.23 "	2430
160	4.93	1090 "	9820	1.47 "	1990	1170 "	10500	1.37 "	2180
180	5.55	1120 "	10100	1.61 "	1830	1190 "	10700	1.51 "	1970
200	6.16	1150 "	10400	1.74 "	1680	–	–	–	–

(c) WESTINGHOUSE No. 4 TRANSFORMER (ABOUT 1200 WATTS CAPACITY).

M	$\frac{M}{l}$	B	$\frac{B}{a}$	$\frac{M}{B}$	$\frac{Bl}{Ma}$
20	0.69	147×10^3	1470	1.36×10^{-4}	2140
40	1.38	406 "	4066	0.98 "	2940
60	2.07	573 "	5730	1.05 "	2770
80	2.76	659 "	6590	1.21 "	2390
100	3.45	714 "	7140	1.40 "	2070
120	4.14	748 "	7490	1.60 "	1810
140	4.83	777 "	7770	1.80 "	1610

(d) THOMSON-HOUSTON 1500 WATTS TRANSFORMER.

M	$\frac{M}{l}$	B	$\frac{B}{a}$	$\frac{M}{B}$	$\frac{Bl}{Ma}$
20	0.42	70×10^3	1560	2.86×10^{-4}	3730
40	0.84	142 "	3160	2.81 "	3780
60	1.26	214 "	4770	2.81 "	3790
80	1.68	265 "	5910	3.02 "	3520
100	2.10	309 "	6890	3.24 "	3280
120	2.52	348 "	7760	3.45 "	3080
160	3.36	408 "	9100	3.92 "	2710
200	4.20	456 "	10200	4.39 "	2430
240	5.04	495 "	11000	4.87 "	2190
280	5.88	524 "	11690	5.35 "	1990
320	6.72	550 "	12270	5.82 "	1820
360	7.56	573 "	12780	6.29 "	1690
400	8.40	591 "	13180	6.78 "	1570
440	9.24	504 "	13470	7.28 "	1460

TABLE 320.

MAGNETO-OPTIC ROTATION.

Solids.

Substance.	Chemical formula.	Density or grammes per c. c.	Kind of light.	Verdet's constant in minutes.	Temp. C.	Authority.
Amber	–	–	D	0.0095	18–20°	Quincke.
Blende	ZnS	–	"	0.2234	15	Becquerel.
Diamond	C	–	"	0.0127	"	"
Fluor spar	$CaFl_2$	–	"	0.0087	"	"
Glass :						
Crown	–	–	"	0.0203	"	"
Faraday A	–	5.458	"	0.0782	18–20	Quincke.
" B	–	4.284	"	0.0649	"	"
Flint	–	–	"	0.0420	"	"
"	–	–	"	0.0325	15	Becquerel.
"	–	–	"	0.0416	"	"
" dense	–	–	"	0.0576	"	"
" "	–	–	"	0.0647	"	"
Plate	–	–	"	0.0406	18–20	Quincke.
Lead borate	PbB_2O_4	–	"	0.0600	15	Becquerel.
Quartz (perpendicular to axis)	–	–	"	0.0172	18–20	Quincke.
Rock salt	NaCl	–	"	0.0355	15	Becquerel.
Selenium	Se	–	B	0.4625	"	"
Sodium borate	$Na_2B_4O_7$	–	D	0.0170	"	"
Spinel (colored by chrome)	–	–	"	0.0209	"	"
Sylvine	KCl	–	"	0.0283	"	"
Ziqueline (suboxide of copper)	Cu_2O	–	B	0.5908	"	"

MAGNETO-OPTIC ROTATION.

Liquids.

Substance.	Chemical formula.	Density in grammes per c. c.	Kind of light.	Verdet's constant in minutes.	Temp. C.	Authority.
ne	C_3H_6O	0.7947	D	0.0113	20	Jahn.
. . . . .	"	0.7957	"	0.0115	15	Perkin.
. . . . .	"	0.7947	"	0.0114	16	Schönrock.
(see also solutions in water)						
tic	$C_2H_4O_2$	1.0561	"	0.0105	21	Perkin.
rric	$C_4H_8O_2$	0.9663	"	0.0116	15	"
nic	CH_2O_2	1.2273	"	0.0105	15	"
rochloric . . .	HCl	1.2072	"	0.0224	15	"
" . . .	"	–	"	0.0206	15	Becquerel.
robromic . . .	HBr	1.7859	"	0.0343	15	Perkin.
roiodic	HI	1.9473	"	0.0513	15	"
ic	HNO_3	1.5190	"	0.0070	13	"
(fuming) . . .	"	–	"	0.0080	15	Becquerel.
ionic	$C_3H_6O_2$	0.9975	"	0.0110	15	Perkin.
huric	H_2SO_4	–	"	0.0121	15	Becquerel.
hurous	H_2SO_3	–	"	0.0153	15	"
ric	$C_5H_{10}O_2$	0.9438	"	0.0121	15	Perkin.
ols:						
l	$C_5H_{11}OH$	–	"	0.0131	15	Becquerel.
. . . . .	"	0.8107	"	0.0128	20	Jahn.
l	C_4H_9OH	0.8021	"	0.0124	20	"
. . . . .	"	–	"	0.0124	15	Becquerel.
l	C_2H_5OH	0.7929	"	0.0107	18–20	Quincke.
. . . . .	"	0.7900	"	0.0112	20	Jahn.
. . . . .	"	0.7944	"	0.0114	15	Perkin.
. . . . .	"	0.7943	"	0.0113	16	Schönrock.
yl	CH_3OH	0.7915	"	0.0094	18–20	Quincke.
. . . . .	"	0.7920	"	0.0093	20	Jahn.
. . . . .	"	–	"	0.0106	15	Becquerel.
. . . . .	"	0.7966	"	0.0096	15	Perkin.
. . . . .	"	0.7903	"	0.0096	21.9	Schönrock.
l	$C_8H_{17}OH$	0.8296	"	0.0134	15	Perkin.
yl	C_3H_7OH	0.8050	"	0.0120	20.8	Schönrock.
. . . . .	"	0.8082	"	0.0120	15.0	Perkin.
. . . . .	"	–	"	0.0118	15	Becquerel.
. . . . .	"	0.8042	"	0.0120	20	Jahn.
ne	C_6H_6	0.8786	"	0.0297	20	Jahn.
. . . . .	"	–	"	0.0268	15	Becquerel.
. . . . .	"	0.8718	"	0.0301	20.9	Schönrock.
les:						
noform	$CHBr_3$	2.9021	"	0.0317	15	Perkin.
l	C_2H_5Br	1.4486	"	0.0183	15	"
lene	$C_2H_4Br_2$	2.1871	"	0.0268	15	"
. . . . .	"	2.1780	"	0.0269	20	Jahn.
yl	CH_3Br	1.7331	"	0.0205	0	Perkin.
ylene	CH_2Br_2	2.4971	"	0.0276	15	"
l	$C_8H_{17}Br$	1.1170	"	0.0164	15	"
yl	C_3H_7Br	1.3600	"	0.0180	15	"
disulphide . . .	CS_2	1.2644	"	0.0441	18–20	Quincke.
" . . .	"	–	"	0.0434	0	Becquerel, 1885.
" . . .	"	–	"	0.0433	0	Gordon.
" . . .	"	–	"	0.0420	18	Rayleigh.
" . . .	"	–	"	0.0420	18	Koepsel.
" . . .	"	–	"	0.0439	0	Arons.

MAGNETO-OPTIC ROTATION.

Liquids.

Substance.	Chemical formula.	Density in grammes per c. c.	Kind of light.	Verdet's constant in minutes.	Temp. C.	Auth
Chlorides:						
Amyl	$CHCl$	0.8740	D	0.0140	20	Jahn.
Arsenic	As	–	"	0.0422	15	Becqu
Carbon	C	–	"	0.0170	15	"
" bichloride	CCl_4	–	"	0.0321	15	"
Chloroform	$CHCl_3$	1.4823	"	0.0164	20	Jahn.
"	"	1.4990	"	0.0166	15	Perkin
Ethyl	C_2H_5Cl	0.9169	"	0.0138	6	"
Ethylene	$C_2H_4Cl_2$	1.2589	"	0.0166	15	"
"	"	1.2561	"	0.0164	20	Jahn.
Methyl	CH_3Cl	–	"	0.0170	15	Becqu
Methylene	CH_2Cl_2	1.3361	"	0.0162	15	Perkin
Octyl	$C_8H_{17}Cl$	0.8778	"	0.0141	15	"
Phosphorus protochloride	PCl_3	–	"	0.0275	15	Becqu
Propyl	C_3H_7Cl	0.8922	"	0.0135	15	Perkin
Silicon	$SiCl_4$	–	"	0.0275	15	Becqu
Sulphur bichloride	S_2Cl_2	–	"	0.0393	15	"
Tin bichloride	$SnCl_4$	–	"	0.0151	15	"
Zinc bichloride	$ZnCl_2$	–	"	0.0437	15	"
Iodides:						
Ethyl	C_2H_5I	1.9417	"	0.0296	15	Perkin
Methyl	CH_3I	2.2832	"	0.0336	15	"
Octyl	$C_8H_{17}I$	1.3395	"	0.0213	15	"
Propyl	C_3H_7I	1.7658	"	0.0271	15	"
Nitrates:						
Ethyl	$C_2H_5O.NO_2$	1.1149	"	0.0091	15	"
Ethylene (nitroglycol)	$C_2H_4(NO_3)_2$	1.4948	"	0.0088	15	"
Methyl	$CH_3O.NO_2$	1.2157	"	0.0078	15	"
Propyl	$C_3H_7O.NO_2$	1.0622	"	0.0100	15	"
Trinitrin (nitroglycerine)	$C_3H_5(NO_3)_3$	1.5996	"	0.0090	15	"
Nitro ethane	$C_2H_5NO_2$	1.0552	"	0.0095	15	"
Nitro methane	CH_3NO_2	1.1432	"	0.0084	15	"
Nitro propane	$C_3H_5NO_2$	1.0100	"	0.0102	15	"
Paraffins:						
Decane	$C_{10}H_{22}$	0.7218	"	0.0128	23.1	Schön
Heptane	C_7H_{16}	0.6880	"	0.0125	15	Perkin
Hexane	C_6H_{14}	0.6580	"	0.0122	22.1	Schön
"	"	0.6743	"	0.0125	15	Perkin
Octane	C_8H_{18}	0.7011	"	0.0128	23.1	Schön
Pentane	C_5H_{12}	0.6196	"	0.0119	21.1	"
"	"	0.6332	"	0.0118	15	Perkin
Phosphorus (melted)	P	–	"	0.1316	33	Becqu
Sulphur (melted)	S	–	"	0.0803	114	"
Toluene	C_7H_8	0.8581	"	0.0269	28.4	Schön
"	"	–	"	0.0243	15	Becqu
Water	H_2O	0.9992	"	0.0130	15	"
"	"	0.9983	"	0.0131	18–20	Quincl
"	"	0.9983	"	0.0132	20	Jahn.
Xylene	C_8H_{10}	–	"	0.0221	15	Becqu
"	"	0.8746	"	0.0263	27	Schön

MAGNETO-OPTIC ROTATION.

Solutions of Acids and Salts in Water.

Substance.	Chemical formula.	Density, grammes per c. c.	Kind of light.	Verdet's constant in minutes.	Temp. C.	Authority.
one	C_8H_6O	0.9715	D	0.0129	20°	Jahn.
s:						
drobromic	HBr	1.7859	"	0.0343	15	Perkin.
"	"	1.6104	"	0.0304	"	"
"	"	1.3775	"	0.0244	"	"
"	"	1.2039	"	0.0194	"	"
"	"	1.1163	"	0.0168	"	"
drochloric	HCl	1.2072	"	0.0225	"	"
"	"	1.1856	"	0.0219	"	"
"	"	1.1573	"	0.0204	"	"
"	"	1.1279	"	0.0193	"	"
"	"	1.0762	"	0.0168	"	"
"	"	1.0323	"	0.0150	20	Jahn.
"	"	1.0158	"	0.0140	"	"
driodic	HI	1.9473	"	0.0513	"	Perkin.
"	"	1.9057	"	0.0499	"	"
"	"	1.8229	"	0.0468	"	"
"	"	1.7007	"	0.0421	"	"
"	"	1.4495	"	0.0323	"	"
"	"	1.2966	"	0.0258	"	"
"	"	1.1760	"	0.0205	"	"
ric	HNO_3	1.5190	"	0.0010	"	"
	"	1.3560	"	0.0105	"	"
phuric + $3H_2O$	H_2SO_4	–	"	0.0121	"	Becquerel.
onia	NH_3	0.8918	"	0.0153	15	Perkin.
ides:						
monium	NH_4Br	1.2805	"	0.0226	"	"
"	"	1.1576	"	0.0186	"	"
ium	$BaBr_2$	1.5399	"	0.0215	20	Jahn.
"	"	1.2855	"	0.0176	"	"
lmium	$CdBr_2$	1.3291	"	0.0192	"	"
"	"	1.1608	"	0.0162	"	"
cium	$CaBr_2$	1.2491	"	0.0189	"	"
"	"	1.1337	"	0.0164	"	"
assium	KBr	1.1424	"	0.0163	"	"
"	"	1.0876	"	0.0151	"	"
lium	NaBr	1.1351	"	0.0165	"	"
"	"	1.0824	"	0.0152	"	"
ontium	$SrBr_2$	1.2901	"	0.0186	"	"
"	"	1.1416	"	0.0159	"	"
nate of potassium	K_2CO_3	1.1906	"	0.0140	20	"
" sodium	Na_2CO_3	1.1006	"	0.0140	"	"
" "	"	1.0564	"	0.0137	"	"
ides:						
monium (sal ammoniac)	NH_4Cl	1.0718	"	0.0178	15	Verdet.
ium	$BaCl_2$	1.2897	"	0.0168	20	Jahn.
"	"	1.1338	"	0.0149	"	"
lmium	$CdCl_2$	1.3179	"	0.0185	"	"
"	"	1.2755	"	0.0179	"	"
"	"	1.1732	"	0.0160	"	"
"	"	1.1531	"	0.0157	"	"
cium	$CaCl_2$	1.1504	"	0.0165	"	"
"	"	1.0832	"	0.0152	"	"
"	"	1.1049	"	0.0157	16	Schönrock.
per	$CuCl_2$	1.5158	"	0.0221	15	Becquerel.
	"	1.2789	"	0.0186	"	"
	"	1.1330	"	0.0156	"	"

TABLE 322 (continued).

MAGNETO-OPTIC ROTATION.

Solutions of Acids and Salts in Water.

...stance.	Chemical formula.	Density, grammes per c. c.	Kind of light.	Verdet's constant in minutes.	Temp. C.	Authority.
. . .	$FeCl_2$	1.4331	D	0.0025	15°	Becquerel
. . .	"	1.2142	"	0.0099	"	"
. . .	"	1.1093	"	0.0118	"	"
. . .	"	1.0548	"	0.0124	"	"
erric) . .	Fe_2Cl_6	1.6933	"	—0.2026	"	"
. . .	"	1.5315	"	—0.1140	"	"
. . .	"	1.3230	"	—0.0348	"	"
. . .	"	1.1681	"	—0.0015	"	"
. . .	"	1.0864	"	0.0081	"	"
. . .	"	1.0445	"	0.0113	"	"
. . .	"	1.0232	"	0.0122	"	"
. . .	LiCl	1.0619	"	0.0145	20	Jahn.
. . .	"	1.0316	"	0.0143	"	"
se . . .	$MnCl_2$	1.1966	"	0.0167	15	Becquerel
. . .	"	1.0876	"	0.0150	"	"
. . .	$HgCl_2$	1.0381	"	0.0137	16	Schönrock
. . .	"	1.0349	"	0.0137	"	"
. . .	$NiCl_2$	1.4685	"	0.0270	15	Becquerel
. . .	"	1.2432	"	0.0196	"	"
. . .	"	1.1233	"	0.0162	"	"
. . .	"	1.0690	"	0.0146	"	"
m . . .	KCl	1.6000	"	0.0163	"	"
. . .	"	1.0732	"	0.0148	20	Jahn.
. . .	"	1.0418	"	0.0144	"	"
. . .	NaCl	1.2051	"	0.0180	15	Becquerel
. . .	"	1.1058	"	0.0155	"	"
. . .	"	1.0546	"	0.0144	"	"
. . .	"	1.0817	"	0.0154	20	Jahn.
. . .	"	1.0418	"	0.0144	"	"
m . . .	$SrCl_2$	1.1921	"	0.0162	"	"
. . .	"	1.0877	"	0.0146	"	"
. . .	$SnCl_2$	1.3280	"	0.0266	15	Verdet.
. . .	"	1.1637	"	0.0198	"	"
. . .	"	1.1112	"	0.0175	"	"
. . .	$ZnCl_2$	1.2851	"	0.0196	"	"
. . .	"	1.1595	"	0.0161	"	"
of potassium .	K_2CrO_4	1.3598	"	0.0098	"	"
te of " .	$K_2Cr_2O_7$	1.0786	"	0.0126	"	"
f mercury .	$Hy(CN)_2$	1.0638	"	0.0136	16	Schönrock
" " .	"	1.0425	"	0.0134	"	"
" " .	"	1.0605	"	0.0135	"	"
ium . . .	NH_4I	1.5948	"	0.0396	15	Perkin.
. . .	"	1.5688	"	0.0386	"	"
. . .	"	1.5109	"	0.0358	"	"
. . .	"	1.2341	"	0.0235	"	"
m . . .	CdI	1.5156	"	0.0291	20	Jahn.
. . .	"	1.2770	"	0.0215	"	"
. . .	"	1.1521	"	0.0177	"	"
um . . .	KI	1.6743	"	0.0338	15	Becquerel
. . .	"	1.3398	"	0.0237	"	"
. . .	"	1.1705	"	0.0182	"	"
. . .	"	1.0871	"	0.0152	"	"
. . .	"	1.2380	"	0.0211	20	Jahn.
. . .	"	1.1245	"	0.0174	"	"
. . .	NaI	1.1939	"	0.0200	"	"
. . .	"	1.1191	"	0.0175	"	"

MAGNETO-OPTIC ROTATION.

TABLE 322. — Solutions of Acids and Salts in Water.

Substance.	Chemical formula.	Density, grammes per c. c.	Kind of light.	Verdet's constant in minutes.	Temp. C.	Authority.
Nitrates:						
Ammonium	NH_4NO_3	1.2803	D	0.0121	15	Perkin.
Potassium	KNO_3	1.0634	"	0.0130	20	Jahn.
Sodium	$NaNO_3$	1.1112	"	0.0131	"	"
Uranium	$U_2O_3.N_2O_5$	2.0267	"	0.0053	"	Becquerel.
"	"	1.7640	"	0.0078	"	"
"	"	1.3865	"	0.0105	"	"
"	"	1.1963	"	0.0115	"	"
Sulphates:						
Ammonium	$(NH_4)_2SO_4$	1.2286	"	0.0140	15	Perkin.
" (acid)	$NH_4.HSO_4$	1.4417	"	0.0085	"	"
Barium	$BaSO_4$	1.1788	"	0.0134	20	Jahn.
"	"	1.0938	"	0.0133	"	"
Cadmium	$CdSO_4$	1.1762	"	0.0139	"	"
"	"	1.0890	"	0.0136	"	"
Lithium	Li_2SO_4	1.1762	"	0.0137	"	"
"	"	1.0942	"	0.0135	"	"
Manganese	$MnSO_4$	1.2441	"	0.0138	"	"
"	"	1.1416	"	0.0136	"	"
Potassium	K_2SO_4	1.0475	"	0.0133	"	"
Sodium	$NaSO_4$	1.0661	"	0.0135	"	"

TABLE 323. — Solutions of Salts in Alcohol.

Substance.	Chemical formula.	Density, grammes per c. c.	Kind of light.	Verdet's constant in minutes.	Temp. C.	Authority.
Cadmium bromide	$CdBr_2$	1.0446	D	0.0159	20	Jahn.
" "	"	0.9420	"	0.0140	"	"
Calcium "	$CaBr_2$	0.9966	"	0.0154	"	"
" "	"	0.8846	"	0.0130	"	"
Strontium "	$SrBr_2$	0.9636	"	0.0140	"	"
" "	"	0.8814	"	0.0126	"	"
Cadmium chloride	$CdCl_2$	0.8303	"	0.0118	"	"
Strontium "	$SrCl_2$	0.8313	"	0.0118	"	"
" "	"	0.8274	"	0.0117	"	"
Cadmium iodide	CdI_2	1.0988	"	0.0199	"	"
" "	"	0.9484	"	0.0156	"	"

TABLE 324. — Solutions in Hydrochloric Acid.

Substance.	Chemical formula.	Density, grammes per c. c.	Kind of light.	Verdet's constant in minutes.	Temp. C.	Authority.
Antimony trichloride	$SbCl_3$	2.4755	D	0.0603	15	Becquerel.
" "	"	1.8573	"	0.0449	"	"
" "	"	1.5195	"	0.0347	"	"
" "	"	1.3420	"	0.0277	"	"
Bismuth "	$BiCl_3$	2.0822	"	0.0396	"	"
" "	"	1.6550	"	0.0359	"	"
" "	"	1.4156	"	0.0350	"	"

TABLE 325. — Magneto-Optic Rotation.

Gases.

Substance.	Pressure.	Temp.	Verdet's constant in minutes.	Authority.
Atmospheric air	Atmospheric	Ordinary	6.83×10^{-5}	Becquerel.
Carbon dioxide	"	"	13.00 "	"
Carbon disulphide	74 cms.	70° C.	23.49 "	Bichat.
Ethylene	Atmospheric	Ordinary	34.48 "	Becquerel.
Nitrogen	"	"	6.92 "	"
Nitrous oxide	"	"	16.90 "	"
Oxygen	"	"	6.28 "	"
Sulphur dioxide	"	"	31.39 "	"
" "	246 cms.	20° C.	38.40 "	Bichat.

Du Bois discusses Kundt's results and gives additional experiments on nickel and cobalt. He shows that in the case of substances like iron, nickel, and cobalt which have a variable magnetic susceptibility the expression in Verdet's equation, which is constant for substances of constant susceptibility, requires to be divided by the susceptibility to obtain a constant. For this expression he proposes the name "Kundt's constant." These experiments of Kundt and Du Bois show that it is not the difference of magnetic potential between the two ends of the medium, but the product of the length of the medium and the induction per unit area, which controls the amount of rotation of the beam.

TABLE 326. — Verdet's and Kundt's Constants.

The following short table is quoted from Du Bois' paper. The quantities are stated in c. g. s. measure, circular measure (radians) being used in the expression of "Verdet's constant" and "Kundt's constant."

Name of substance.	Magnetic susceptibility.	Verdet's constant.		Wave-length of light in cms.	Kundt's constant.
		Number.	Authority.		
Cobalt	—	—	—	6.44×10^{-5}	3.99
Nickel	—	—	—	"	3.15
Iron	—	—	—	6.56 "	2.63
Oxygen : 1 atmo.	$+0.0126 \times 10^{-5}$	0.000179×10^{-5}	Becquerel.	5.89 "	0.014
Sulphur dioxide	-0.0751 "	0.302 "	"	" "	—4.00
Water	-0.0694 "	0.377 "	Arons	"	—5.4
Nitric acid	-0.0633 "	0.356 "	Becquerel.	"	—5.6
Alcohol	-0.0566 "	0.330 "	De la Rive.	"	—5.8
Ether	-0.0541 "	0.315 "	"	"	—5.8
Arsenic chloride	-0.0876 "	1.222 "	Becquerel.	"	—14.9
Carbon disulphide	-0.0716 "	1.222 "	Rayleigh.	"	—17.1
Faraday's glass	-0.0982 "	1.738 "	Becquerel.	"	—17.7

TABLE 327.—Magnetic Susceptibility of Liquids and Gases.

wing table gives a comparison by Du Bois* of his own and some other determinations of the magnetic sus-ility of a few standard substances. Verdet's and Kundt's constants are in radians for the sodium line D.

Substance.	Verdet's constant.	Faraday's value $k \times 10^6$	Becquerel's value $k \times 10^6$	Wähner's value $k \times 10^6$
ter	3.77×10^{-6}	—0.69	—0.63	—0.536
hol, C_2H_6O . . .	3.30 "	—0.57	—0.49	—0.388
er, $C_4H_{10}O$ . . .	3.15 "	—0.54	-	—0.360
on disulphide . .	12.22 "	—0.72	—0.84	—0.465
gen at 1 atmosphere .	0.00179 "	0.13	0.12	-
at 1 atmosphere . .	0.00194 "	0.024	0.025	-

Substance.	Quincke at 20° C.		Du Bois at 15° C.		
	Density.	$k \times 10^6$	Density.	$k \times 10^6$	Kundt's constant.
ter	0.9983	—0.815	0.9992	—0.837	—4.50
hol, C_2H_6O . . .	0.7929	—0.660	0.7963	—0.694	—4.75
er, $C_4H_{10}O$ . . .	0.7152	—0.607	0.7250	—0.642	—4.91
on disulphide . .	1.2644	—0.724	1.2692	—0.816	—14.97
gen at 1 atmosphere .	-	-	0.00135	0.117	0.016
at 1 atmosphere . .	-	-	0.00123	0.024	0.081

TABLE 328.—Values of Kerr's Constant.†

as shown that the rotation of the major axis of vibration of radiations normally reflected from a magnet is ically equal to the normal component of magnetization multiplied into a constant K. He calls this con-K, Kerr's constant for the magnetized substance forming the magnet.

Color of light.	Spectrum line.	Wave-length in cms. $\times 10^6$	Kerr's constant in minutes per c. g. s. unit of magnetization.			
			Cobalt.	Nickel.	Iron.	Magnetite.
. . .	Li α	67.7	—0.0208	—0.0173	—0.0154	+0.0096
. . .	—	62.0	—0.0198	—0.0160	—0.0138	+0.0120
ow . . .	D	58.9	—0.0193	—0.0154	—0.0130	+0.0133
n . . .	b	51.7	—0.0179	—0.0159	—0.0111	+0.0072
. . .	F	48.6	—0.0180	—0.0163	—0.0101	+0.0026
et . . .	G	43.1	—0.0182	—0.0175	—0.0089	-

* "Wied. Ann." vol. 35, p. 163.

† H. E. J. G. Du Bois, "Phil. Mag." vol. 29.

TABLE 329. — Variation of Resistance of Bismuth, with Temperature, in a Transverse Magnetic Field.

	Proportional Values of Resistance.								
H	−192°	−135°	−100°	−37°	0°	+18°	+60°	+100°	+183°
0	0.40	0.60	0.70	0.88	1.00	1.08	1.25	1.42	1.79
2000	1.16	0.87	0.86	0.96	1.08	1.11	1.26	1.43	1.80
4000	2.32	1.35	1.20	1.10	1.18	1.21	1.31	1.46	1.82
6000	4.00	2.06	1.60	1.29	1.30	1.32	1.39	1.51	1.85
8000	5.90	2.88	2.00	1.50	1.43	1.42	1.46	1.57	1.87
10000	8.60	3.80	2.43	1.72	1.57	1.54	1.54	1.62	1.89
12000	10.8	4.76	2.93	1.94	1.71	1.67	1.62	1.67	1.92
14000	12.9	5.82	3.50	2.16	1.87	1.80	1.70	1.73	1.94
16000	15.2	6.95	4.11	2.38	2.02	1.93	1.79	1.80	1.96
18000	17.5	8.15	4.76	2.60	2.18	2.06	1.88	1.87	1.99
20000	19.8	9.50	5.40	2.81	2.33	2.20	1.97	1.95	2.03
25000	25.5	13.3	7.30	3.50	2.73	2.52	2.22	2.10	2.09
30000	30.7	18.2	9.8	4.20	3.17	2.86	2.46	2.28	2.17
35000	35.5	20.35	12.2	4.95	3.62	3.25	2.69	2.45	2.25

TABLE 330. — Increase of Resistance of Nickel due to a Transverse Magnetic Field, expressed as % of Resistance at 0° and H = 0.

H	−190°	−75°	0°	+18°	+100°	+182°
0	+0	0	0	0	0	0
1000	+0.20	+0.23	+0.07	+0.07	+0.96	+0.04
2000	+0.17	+0.16	+0.03	+0.03	+0.72	−0.07
3000	0.00	−0.05	−0.34	−0.36	−0.14	−0.60
4000	−0.17	−0.15	−0.60	−0.72	−0.70	−1.15
6000	−0.19	−0.20	−0.70	−0.83	−1.02	−1.53
8000	−0.19	−0.23	−0.76	−0.90	−1.15	−1.66
10000	−0.18	−0.27	−0.82	−0.95	−1.23	−1.76
12000	−0.18	−0.30	−0.87	−1.00	−1.30	−1.85
14000	−0.18	−0.32	−0.91	−1.04	−1.37	−1.95
16000	−0.17	−0.35	−0.94	−1.09	−1.44	−2.05
18000	−0.17	−0.38	−0.98	−1.13	−1.51	−2.15
20000	−0.16	−0.41	−1.03	−1.17	−1.59	−2.25
25000	−0.14	−0.49	−1.12	−1.29	−1.76	−2.50
30000	−0.12	−0.56	−1.22	−1.40	−1.95	−2.73
35000	−0.10	−0.63	−1.32	−1.50	−2.13	−2.98

F. C. Blake, Ann. der Physik, 28, p. 449; 1909.

TABLE 331. — Change of Resistance of Various Metals in a Transverse Magnetic Field. Room Temperature.

Metal.	Field Strength in Gausses.	Per cent Increase.	Authority.
Nickel	10000	−1.2	Williams, Phil. Mag. 9, 1905.
"	"	−1.4	Barlow, Pr. Roy. Soc. 71, 1903.
"	6000	−1.0	Dagostino, Atti Ac. Linc. 17, 1908.
"	10000	−1.4	Grummach, Ann. der Phys. 22, 1906.
Cobalt	"	−0.53	"
Cadmium	"	+0.03	"
Zinc	"	+0.01	"
Copper	"	+0.004	"
Silver	"	+0.004	"
Gold	"	+0.003	"
Tin	"	+0.002	"
Palladium	"	+0.001	"
Platinum	"	+0.0005	"
Lead	"	+0.0004	"
Tantalum	"	+0.0003	"
Magnesium	6000	+0.01	Dagostino, *l. c.*
Manganin	"	+0.01	"
Tellurium	?	+0.02 to 0.34	Goldhammer, Wied Ann. 31, 1887.
Antimony	?	+0.02 to 0.16	"
Iron	Different specimens show very diverse results, usually an increase in weak fields, a decrease in strong.		Grummach, *l. c.* Barlow, *l. c.* Williams, *l. c.*
Nickel steel	Alloys behave similarly to Iron.		Williams, *l. c.*

TABLE 332.—Transverse Galvanomagnetic and Thermomagnetic Effects.

Effects are considered positive when, the magnetic field being directed away from the observer, nd the primary current of heat or electricity directed from left to right, the upper edge of the pecimen has the higher potential or higher temperature.

E = difference of potential produced; T = difference of temperature produced; I = primary urrent; $\frac{dt}{dx}$ = primary temperature gradient; B = breadth, and D = thickness, of specimen; H = intensity of field. C. G. S. units.

Hall effect (Galvanomagnetic difference of Potential), $E = R\frac{HI}{D}$

Ettingshausen effect (" " " Temperature), $T = P\frac{HI}{D}$

Nernst effect (Thermomagnetic " " Potential), $E = QHB\frac{dt}{dx}$

Leduc effect (" " " Temperature), $T = SHB\frac{dt}{dx}$

Substance.	Values of R.	$P \times 10^6$.	$Q \times 10^6$.	$S \times 10^8$.
Tellurium	+400 to 800	+200	−360000	+400
Antimony	+ 0.9 " 0.22	+2	+9000 to 18000	+200
Steel	+.012 " 0.033	−0.07	−700 " 1700	+69
Hensler alloy	+.010 " 0.026	-	+1600 " 7000	
Iron	+.007 " 0.011	−0.06	−1000 " 1500	+39
Cobalt	+.0016 " 0.0046	+0.01	+1800 " 2240	+13
Zinc	-	-	−54 " 240	+13
Cadmium	+.00055			
Iridium	+.00040	-	up to −5.0	+5
Lead	+.00009	-	−5.0 (?)	
Tin	−.00003	-	−4.0 (?)	
Platinum	−.0002	-	-	−2
Copper	−.00052	-	−90 to 270	−18
German silver	−.00054			
Gold	−.00057 to .00071			
Constantine	−.0009			
Manganese	−.00093			
Palladium	−.0007 to .0012	-	+50 to 130	−3
Silver	−.0008 " .0015	-	−46 " 430	−41
Sodium	−.0023			
Magnesium	−.00094 to .0035			
Aluminum	−.00036 " .0037			
Nickel	−.0045 " .024	+0.04 to 0.19	+2000 " 9000	−45
Carbon	−.017	+5.	+100	
Bismuth	− up to 16.	+3 to 40	− up to 132000	−200

TABLE 333.—Variation of Hall Constant with the Temperature.

Bismuth.[1]						Antimony.[2]				
H	−182°	−90°	−23°	+11.5°	+100°	H	−186°	−79°	+21.5°	+58°
1000	62.2	28.0	17.0	13.3	7.28	1750	0.263	0.249	0.217	
2000	55.0	25.0	16.0	12.7	7.17	3960	0.252	0.243	0.211	
3000	49.7	22.9	15.1	12.1	7.06	6160	0.245	02.35	0.209	0.203
4000	45.8	21.5	14.3	11.5	6.95					
5000	42.6	20.2	13.6	11.0	6.84					
6000	40.1	18.9	12.9	10.6	6.72					

Bismuth.[3]									
H	+14.5°	+104°	125°	189°	212°	239°	259°	269°	270°
890	5.28	2.57	2.12	1.42	1.24	1.11	0.97	0.83	0.77*

[1] Barlow, Ann. der Phys. 12, 1903.
[2] Traubenberg, Ann. der Phys. 17, 1905.
[3] Everdingen, Comm. Phys. Lab. Leiden, 58.
* Melting-point.

Both tables taken from Jahn, Jahrbuch der Radioactivität und Electronik, 5, p. 166; 1908, who has collected data of all observers and gives extensive bibliography.

APPENDIX I.

TABLES 334, 335.

THE SPECIFIC HEAT OF IRON AT HIGH TEMPERATURES.

Analysis of iron — (0.01 C, .02 Si, .03 S, .04 P, trace Mn).

TABLE 334. — Mean Specific Heat between 0° and T° Centigrade, S_0^T.

T	S_0^T	T	S_0^T
200°	0.1175	700°	0.1487
250	.1204	750	.1537
300	.1233	800	.1597
350	.1257	850	.1647
400	.1282	900	.1644
450	.1311	950	.1612
500	.1338	1000	.1557
550	.1361	1050	.1512
600	.1396	1100	.1534
650	.1440		

TABLE 335. — Total Heat between 0° and T° Centigrade, Q_0^T.

T	Q_0^T Pionchon's value recalculated.	Q_0^T Harker's value.
200	23.5	23.5
300	36.8	37.0
400	51.6	51.3
500	66.0	66.9
600	83.2	83.8
700	102.2	104.1
800	125.0	127.8
900	146.7	148.0
1000	166.0	155.7
1100	–	168.8

J. A. Harker, Proc. Physical Society, London, 19, p. 703; 1905.
Pionchon's data, based on experiments made many years ago, should be regarded only as corroborative of the more recent and careful experiments of Harker.

APPENDIX II.

DEFINITIONS OF UNITS.

CTIVITY. Power or rate of doing work; unit, the watt.

MPERE. Unit of electrical current. The international ampere, "which is one tenth of the unit of current of the C. G. S. system of electro-magnetic units, and which is represented sufficiently well for practical use by the unvarying current which, when passed through a solution of nitrate of silver in water, and in accordance with accompanying specifications" (*see* pages xxxiv and 251), "deposits silver at the rate of 0.001118 of a gramme per second."

The ampere = 1 coulomb per second = 1 volt through 1 ohm;

Amperes = volts/ohms = watts/volts = $(\text{watts/ohms})^{\frac{1}{2}}$.

Amperes × volts = $\text{amperes}^2 \times \text{ohms}$ = watts.

NGSTRÖM. Unit of wave-length = 10^{-10} metre.

TMOSPHERE. Unit of pressure.

English normal = 14.7 pounds per sq. in. = 29.929 in. = 760.18 mm. Hg. 32° F.

French " = 760 mm. of Hg. 0° C. = 29.922 in. = 14.70 lbs. per sq. in.

ARAD. C. G. S. unit of pressure = 1 dyne per sq. cm.

DUGIE DECIMALE. Photometric standard; *see* page 177.

RITISH THERMAL UNIT. Heat required to raise one pound of water at its temperature of maximum density, 1° F. = 252 gramme-calories.

ALORY. Small calory = gramme-calory = therm = quantity of heat required to raise one gramme of water at its maximum density, one degree Centigrade.

Large calory = kilogramme-calory = 1000 small calories = one kilogramme of water raised one degree Centigrade at the temperature of maximum density.

For conversion factors *see* page 227.

ANDLE. Photometric standard, *see* page 177.

ARAT. The diamond carat = 3.168 grains = 0.2053 grammes.

The gold carat: pure gold is 24 carats; a carat is 1/24 part.

ARCEL. Photometric standard; *see* page 177.

IRCULAR AREA. The square of the diameter = 1.2733 × true area.

True area = 0.785398 × circular area.

OULOMB. Unit of quantity. The international coulomb is the quantity of electricity transferred by a current of one international ampere in one second.

Coulombs = (volts-seconds)/ohms = amperes × seconds.

UBIT = 18 inches.

AY. Mean solar day = 1440 minutes = 86400 seconds = 1.0027379 sidereal day.

Sidereal day = 86164.10 mean solar seconds.

IGIT. 3/4 inch; 1/12 the diameter of the sun or moon.

YNE. C. G. S. unit of force = that force which acting for one second on one gramme produces a velocity of one centimetre per second.

= weight in grammes divided by the acceleration of gravity in cm. per sec.

NERGY. *See* Erg.

RG. C. G. S. unit of work and energy = one dyne acting through one centimetre.

For conversion factors *see* page 227.

ARAD. Unit of electrical capacity. The international farad is the capacity of a condenser charged to a potential of one international volt by one international coulomb of electricity.

The one-millionth part of a farad (microfarad) is more commonly used.

Farads = coulombs/volts.

OOT-POUND. The work which will raise one pound one foot high.

For conversion factors *see* page 227.

OOT-POUNDALS. The English unit of work = foot-pounds/g.

For conversion factors *see* page 227.

The acceleration produced by gravity.

AUSS. A unit of intensity of magnetic field = 10^8 C. G. S. units.

RAMME. *See* page 6.

GRAMME–CENTIMETRE. The gravitation unit of work = g. ergs.
For further conversion factors *see* page 227.

HEAT UNIT. *See* Calory.

HEAT OF THE ELECTRIC CURRENT generated in a metallic circuit without self-induction is proportional to the quantity of electricity which has passed in coulombs multiplied by the fall of potential in volts, or is equal to (coulombs × volts)/4.181 in small calories.

The heat in small or gramme-calories per second = (amperes^2 × ohms)/4.181 = volts^2/(ohms × 4.181) = (volts × amperes)/4.181 = watts/4.181.

HEAT. Absolute zero of heat = −273° Centigrade, −459.4° Fahrenheit, −218.4° Reaumur.

HEFNER UNIT. Photometric standard; *see* page 177.

HENRY. Unit of induction. It is "the induction in a circuit when the electromotive force induced in this circuit is one international volt, while the inducing current varies at the rate of one ampere per second."

HORSE–POWER. The practical unit of power = 33,000 pounds raised one foot per minute.

JOULE. Unit of work = 10^7 ergs.
Joules = (volts^2 × seconds)/ohms = watts × seconds = amperes^2 × ohms × sec.
For conversion factors *see* page 227.

JOULE'S EQUIVALENT. The mechanical equivalent of heat = 4.181 × 10^7 ergs. *See* page 227.

KILODYNE. 1000 dynes. About 1 gramme.

LITRE. *See* page 6.

MEGABAR. Unit of pressure = 0.987 atmospheres.

MEGADYNE. One million dynes. About one kilogramme.

METRE. *See* page 6.

METRE CANDLE. The intensity lumination due to standard candle distant one metre.

METRET. An exponential subdivision of the metre. The ordinal number before the word metre denotes the power of ten serving as the divisor; e. g., a tenth-metret = 10^{-10} = $1/10^{10}$ metre. The first metret is the decimetre, the second, the centimetre, etc.

MHO. The unit of electrical conductivity. It is the reciprocal of the ohm.

MICRO. A prefix indicating the millionth part.

MICROFARAD. One millionth of a farad, the ordinary measure of electrostatic capacity.

MICRON. (μ) = one millionth of a metre.

MIL. One thousandth of an inch.

MILE. *See* pages 5, 6.

MILE, NAUTICAL or GEOGRAPHICAL = 6080.204 feet.

MILLI–. A prefix denoting the thousandth part.

MONTH. The anomalistic month = time of revolution of the moon from one perigee to another = 27.55460 days.

The nodical month = draconitic month = time of revolution from a node to the same node again = 27.21222 days.

The sidereal month = the time of revolution referred to the stars = 27.32166 days (mean value), but varies by about three hours on account of the eccentricity of the orbit and "perturbations."

The synodic month = the revolution from one new moon to another = 29.5306 days (mean value) = the ordinary month. It varies by about 13 hours.

OHM. Unit of electrical resistance. The international ohm is based upon the ohm equal to 10^9 units of resistance of the C. G. S. system of electromagnetic units, and "is represented by the resistance offered to an unvarying electric current by a column of mercury, at the temperature of melting ice, 14.4521 grammes in mass, of a constant cross section and of the length of 106.3 centimetres."

International ohm = 1.01367 B. A. ohms = 1.06292 Siemens' ohms.

B. A. ohm = 0.98651 international ohms.

Siemens' ohm = 0.94080 international ohms. *See* page 261.

PENTANE CANDLE. Photometric standard. *See* page 177.

PI = π = ratio of the circumference of a circle to the diameter = 3.14159265359.

POUNDAL. The British unit of force. The force which will in one second impart a velocity of one foot per second to a mass of one pound.

RADIAN = 180°/π = 57.29578° = 57° 17′ 45″ = 206625″.

SECOHM. A unit of self-induction = 1 second × 1 ohm.

THERM = small calory = quantity of heat required to warm one gramme of water at its temperature of maximum density one degree Centigrade.

THERMAL UNIT, BRITISH = the quantity of heat required to warm one pound of water at its temperature of maximum density one degree Fahrenheit = 252 gramme-calories.

VOLT. The unit of electromotive force (E. M. F.). The international volt is "the electromotive force that, steadily applied to a conductor whose resistance is one international ohm, will produce a current of one international ampere, and which is represented sufficiently well for practical use by 1000/1434 of the electromotive force be-

tween the poles or electrodes of the voltaic cell known as Clark's cell, at a temperature of 15° C and prepared in the manner described in the accompanying specification." *See* pages xxxiv and 251.

'OLT-AMPERE. Equivalent to Watt.

VATT. The unit of electrical power = 10^7 units of power in the C. G. S. system. It is represented sufficiently well for practical use by the work done at the rate of one Joule per second.

Watts = volts × amperes = amperes^2 × ohms = volts^2/ohms.

For conversion factors *see* page 227.

Watts × seconds = Joules.

VEBER. A name formerly given to the coulomb.

'EAR. *See* page 108.

Anomalistic year	=	365	days,	6	hours,	13	minutes,	48 seconds.
Sidereal	"	= 365	"	6	"	9	"	9·314 seconds.
Ordinary	"	= 365	"	5	"	48	"	46+ "
Tropical	"	same as the ordinary year.						

INDEX.

For the definitions of units, see Appendix.

PAGE.

rration constant 109
orption of gases by liquids 141
orption of light: atmospheric 179
color screens 195
Jena glasses 193
various crystals 194
eleration of gravity 104–107
odynamic data: soaring data 123
wind pressures 122
nic line 115
: density 160
thermometer, comparisons 234
: transmissibility of, for radiation 179
ohol: density 98–100
vapor pressure 146
viscosity 126
ys: densities 89
electrical conductivity of 266–268
resistance of 262–268
low temp. 264
melting-points 214
specific heats 230
thermal conductivity 199
thermoelectric powers 258–259
rnating currents, resistance of wires for . . 269
minum wire, weights of 64
ms: indices of refraction 181
illogarithms 26–28
eous solutions: boiling-points 219
densities 92
alcohols 98
alcohol, temperature var'n 100
diffusion of 136
electrolytic conductivities 272–278
eous vapor: vapor pressure, low temp . . . 151
0° to 100° C . 152
100° to 230° C . 153
pressure of, in atmosphere . . 155
(saturated) weight of 154
onomical data 108–109
osphere, aqueous vapor in 155
transmissibility for radiation . . . 179
mic weights 270

ometer: boiling temperature of water for various heights 168–169
correction for capillarity 121
latitude, inch . . . 119
metric . . 120
sea level 118
temperature 117
heights, determination of, by . . . 167
teries: composition, electromotive forces . . 252
umé scale: conversion to densities 84
mingham wire gauge 59
muth, resistance of, in magnetic field . . . 306
lack-body" radiation 238
ling-points: chemical elements 210
inorganic compounds 213
organic compounds 215
ling-point, raising of, by salts in solution . . 219
of water and barometric pressure . 168
ss wire, weights of, common measure . . . 60
metric measure . . . 62
ck, crushing strength of 71
tish wire gauge 59
tish weights and measures 7–10

dmium line, wave-length red 170
adle power, standard 177
pacity, specific inductive: crystals 284
gases 279
liquids 280
liquid gases . . . 282

PAGE.

Capacity, specific inductive: solids 283
Capillarity, correction to barometer for . . . 121
liquids 142–143
liquids near solidifying point . . . 143
salt solutions in water 142
thickness of soap films 143
Carcel unit 177
Cells, voltaic: composition, E. M. F. . . . 252–253
double-fluid 253
secondary 253
single-fluid 252
standard 251, 253
storage 253
Chemical, electro-, equivalents 270
equivalent of silver 251
Chemical elements: atomic weights 270
boiling-points 210
compressibility 76
conductivity, thermal . . . 199
densities 85, 91
electro-chemical equivalents 270
hardness 76
melting-points 209
resistance, electrical . 262–263
specific heats 228
thermal conductivities . . 199
expansion, linear . 222
Circular functions: argument (°) 30
(radians) 35
Coals, heat of combustion of 202
Cobalt, magnetic properties of 293
Color screens 195–196
Combination, heat of 204
Combustion, heat of: coals 202
explosives 203
fuels (liquid) 202
peats 202
Compressibility: chemical elements 76
gases 79–81
liquids 82
solids 83
Concretes: resistance to crushing 71
Conductivity, electrical: *see* Resistance.
alloys 266–268
alternating currents, effect of . 269
magnetic field, effect of . . . 306
electrolytic. 272–278
equivalent . . . 275–278
ionic (separate ions) . . 278
specific molecular . . . 273
limiting values 274
temp'ture coef. 274
glass and porc'l'n, temp'ture coef. 285
Conductivity, thermal: gases 200
liquids 200
salt solutions 200
solids 199
water 200
Contact differences of potential 254–256
Convection, cooling by 239–240
Conversion: Beaumé to specific gravities . . . 84
factors for work units 227
Cooling by radiation, perfect radiator . . . 238
and convection . . 239–240
Cosines, hyperbolic natural 41
logarithmic 42
Critical data for gases 221
Crushing, resistance to: bricks 71
concretes 71
stones 71
timber, wood 72
Cubical thermal expansion: gases 226
liquids 225
solids 224

Crystals: dielectric constant 284
elasticity 77–78
expansion, cubical thermal 224
transmissibility for radiation 194
Current, absolute, measures 251
Cyclic magnetization, energy losses in . . 294–296

Declination, secular change of magnetic . . . 110
Demagnetizing factors for rods 289
Density: air: values of $h/760$ 100
alcohol: aqueous ethyl 98
methyl 98
temperature variation . . . 100
alloys 89
aqueous alcohol 98
salt, acid, basic solutions . . 92
chemical elements 85, 91
earth 108
gases 91
liquids 90
mercury 97
metals 85
organic compounds 215
water 95–96
woods 87
Dew points 156
Dielectric constant: (specific inductive capacity)
calibration, standards for . 283
gases, atm. pressure . . 279
pressure coef. . . 279
temperature coef. . 280
liquids 280
temperature coef. . 282
solids 283
Dielectric strength: air: alternating potential . 248
steady potential . . . 248
kerosene 250
large spark-gaps . . . 249
pressure effect . . . 249
various materials . . 250
Difference of potential:
cells: double fluid 253
secondary 253
single fluid 252
standard 251, 253
storage 253
contact: liquids-liquids in air . 254
metals in salt solutions 257
salts with liquids . . 254
solids-solids in air . . 256
thermo-electric 258
platinum couples 259
Differential formulæ 12
Diffusion: aqueous solutions, water 136
gases and vapors: coefficients . . . 138
metals into metals 138
vapors 137
Diffusion integral 50
Dip, magnetic 112
secular change 112
Dynamical equivalent of thermal unit 227

e, value of 12
e^x, e^{-x}, and their logarithms 43, 47
log. e^x, x from 10 to 30 44
e^{x^2}, e^{-x^2}, and their logarithms 45
$e^{\frac{\pi}{4}x}$, $e^{-\frac{\pi}{4}x}$, and their logarithms 46
$e^{\sqrt{\frac{\pi}{4}}x}$, $e^{-\sqrt{\frac{\pi}{4}}x}$, and their logarithms 46
$\frac{e^x+e^{-x}}{2}$, and their logarithms 41, 42
$\frac{e^x-e^{-x}}{2}$ " " " 39, 40
Earth: densities 108
miscellaneous data 108
Elasticity: crystals 77, 78
moduli of rigidity 74
modulus, Young's 75
Electrical conductivity: alloys 266–268
alternating current, effect of 269
magnetic field, effect of . . 306
Electrical resistance: *see* Conductivity.
metals and alloys, low temp. 264
ohm, various determinations 261
specific: metallic wires . . 262
metals 263
temperature effect, glass . 285
Electricity, specific heat of 258
Electric units, dimensional formulæ xxvi
Electrochemical equivalents 270, 272
silver 251
Electrolytic conductivity: 272–278
dilute solutions 272
equivalent § 275–278
ionic 278
specific molecular 273
limiting values 274
temp. coef. . 274
Electromagnetic system of units xxix
Electromagnetic/electrostatic units = v . . . 247
Electromotive force: cells: double fluid . . . 253
secondary 253
single fluid 252
standard . . . 251, 253
storage 253
liquids-liquids in air . . 254
metals in salt solutions . . 257
salts with liquids 254
solids-solids in air . . . 256
thermo-electric 258
(platinum) . 259
Elements: atomic weights 270
boiling-points 210
compressibility 76
conductivity, thermal 199
densities 85, 91
electrochemical equivalents 270
hardness 76
melting-points 200
resistance, electrical 263
specific heats 228
spectra (prominent lines) 170
thermal conductivities 199
expansion, linear 222
cubical, gases . . 226
Elliptic integrals 57
Emission of perfect radiator 238
Equivalent, electro-chemical: elements . . . 270
ionic 272
silver 251
Equivalent, mechanical, of heat 227
Energy, data relating to solar 179
Ethyl alcohol, specific gravity of aqueous . . . 98
Ettinghausen effect 307
Expansion, thermal: cubical, crystals 224
gases 226
liquids 225
solids 224
linear, elements 222
various 223
perfect gas 162
Explosives, composition, etc. 203
Exponential functions: e^x, e^{-x}, their logs. . . 43, 47
log. e^x, $x = 10$ to 30 . . 44
e^{x^2}, e^{-x^2}, their logs . . . 45
$e^{\frac{\pi}{4}x}$, $e^{-\frac{\pi}{4}x}$ " " . . . 46
$e^{\sqrt{\frac{\pi}{4}}x}$, $e^{-\sqrt{\frac{\pi}{4}}x}$, their logs. 46
$\frac{e^x+e^{-x}}{2}$, their logs. . . 41, 42
$\frac{e^x-e^{-x}}{2}$ " " . . 39, 40
diffusion integral . . . 50
hyperbolic sines . . . 39
cosines . . 41
logs. hyperbolic sines . 40
cosines . 42
probability integral . 47, 48
Eye, sensitiveness of, to radiation 178

Fabry-Buisson, standard arc Fe wave-lengths . 170
Factorials, $n!$ 38
Fechner's law 178
Field: earth's magnetic field, components of 110–115
magnetic, behavior of metals in . . 286–296
resistance of metals in 306
rotation of plane of polarization 297–304
thermo-, galvanometric effects . . 307
Films, thin: thickness, colors, tension of . 142, 143
Fluorite: index of refraction 184
Formulæ, conversion: dynamic units 3
electric " 3
fundamental 3
geometric 3

Formulæ, conversion: heat 3
magnetic 3
see INTRODUCTION.
Fraunhofer lines, wave-lengths of 176
Freezing mixtures 220
Freezing-points, lowering of, by salts in solution 217
Friction, coefficients of 124
Fuels, heats of combustion of 202
Functions: circular arguments (° ′) 30
(radians) . . . 35
exponential 39–47
gamma 52, 38
hyperbolic 39–42
Fundamental units 2
Fusion, latent heat of 208

Galvanometric effects of magnetic field . . . 307
Gamma function 52, 38
Gases: absorption of, by liquids 140, 141
atomic weights 270
compressibility of 79–81
conductivity, thermal 200
critical data for 221
densities 91
dielectric constants 279, 280
diffusion 138
expansion of perfect 162
expansion, thermal 226
heat, conductivity for 200
indices of refraction 190
magnetic susceptibility 305
magneto-optic rotation 304
refractive indices of 190
sound, velocity of, in 102
solubility of 140, 141
specific heats 232
thermal conductivity 200
thermal expansion 226
viscosity of 134
volume of perfect (1+0.00376*t*) . . 162–166
Gas thermometry 233–235
Gauges, wire: Birmingham 59
British standard 59
Brown and Sharp 66
Geodetic data 108
Geometric units, conversion factors for . . . 2
Glass: indices of refraction 180
transmissibility of Jena 193
various 195–196
electric resistance, temp. variation . . 285
Glass vessels, volumes of 11
Gravity, force of 104–106
correction to barometer 118
Gyration, radii of 58

Hall effect 307
Hardness 76
Harmonics, zonal 54
Heat: combination, heat of 204
combustion: coals 202
explosives 203
fuels liquid 202
peats 202
conductivity for: gases 200
liquids 200
salt solutions 200
solids 199
water 200
latent heat of fusion 208
vaporization 206, 241
mechanical equivalent of 227
specific: elements 228
gases 232
liquids 230
mercury 229
minerals 231
rocks 231
solids 230
vapors 232
water 229
"Heat, specific," of electricity 258
Hefner photometric unit 177
Heights determinations of by barometer . . . 167
Horizontal intensity of earth's field 114
secular change 114
Humidity, relative 158
Humidity term, 0.378*e* 159
Hydrogen thermometer 233
Hyperbolic cosines, natural 41
logarithmic 42
Hyperbolic sines, natural 39
logarithmic 40

Hysteresis: soft iron cable transformer 294
wire 294
steel, transformer 296
various substances 295

Iceland spar, refractive index of 184
Inclination (dip) of magnetic needle 112
secular change of 112
Index of refraction: alums 181
crystals 187
fluorite 184
gases and vapors 190
glass 180
Iceland spar 184
liquids 189
metals, metallic oxides . . 182
monorefringent solids . . 186
nitroso-dimethyl-aniline . 184
quartz 185
rock-salt 183
salt solutions 188
silvine 186
solids, isotropic 186
Inductance, table for computing mutual . . . 56
Inductive capacity, specific: calibration st'ds . 283
gases, atm. pressure 279
pressure coef. 279
temp. coef. . 280
liquids 280
temp. coef. . 282
solids 283
Inertia, table of moments of 58
Inorganic compounds: boiling-points 213
melting-points . . . 211
Integral, diffusion 50
elliptic 57
gamma function 52
probability 45, 47–48
Integrals, elementary 12
Intensity, horizontal, of earth's field 113
secular variation 113
total, of earth's field 114
secular variation 114
Ionization of water 278
Ions: equivalent conductivity of 278
Iron: hysteresis in soft 294
magnetic properties of, weak fields . . . 294
saturated . . . 293
permeabilities 286–292
specific heat at high temperatures . . . 308
standard arc lines, Fabry-Buisson . . . 170
Kayser 174

Joule's (mechanical) equivalent of heat . . . 227

Kayser's standard iron arc spectrum 174
Kerosene, dielectric strength 250
Kerr's constant 305
Kundt's constant 304
definition of 304

Latent heat of fusion 208
vaporization 206, 241
Latitude correction to barometer 119–120
Least squares 47–49
Legal electrical units xxxiv
Leduc thermomagnetic effect 307
Light: indices of refraction 181–190
reflection of; function of "*n*" 191
metals 192
sensitiveness of eye to 178
transmissibility to, of substances . 193–196
polarized: rotation of plane by solutions 197
rotation, magneto . . . 297–304
wave-lengths: cadmium st'd line . . . 170
elements, brighter lines . 170
Fraunhofer, lines . . . 176
st'd iron arc, Fabry . . 170
Kayser . . 174
solar, Rowland . . 171
velocity of 109
Linear thermal expansion coef. of elements . . 222
various . . . 223
Liquids: absorption of gases by 141
capillarity of 142–143
compressibility of 82–83
conductivity, thermal 200
densities 85, 90, 95–96
dielectric constants 280–282
dielectric strength 250
diffusion, aqueous solutions 136
expansion, thermal 225

Liquids: fuels, heat of combustion 202
magnetic susceptibility 305
magneto-optic rotation 304
potential differences with liquids . . 254
metals . . 257
salts . . . 254
specific heats 230
surface tensions 142–143
thermal conductivity 200
expansion 225
vapor pressures 144–153
velocity of sound 102
viscosity 127–128
Logarithms 24
1000–2000 22
anti- 26
.9000–1.0000 28
Lowering of freezing-points by salts 217

Maclaurin's theorem 12
Magnetic field: bismuth, resistance in 306
Ettingshausen effect 307
galvanomagnetic effects . . . 307
Hall effect 307
Leduc effect 307
Nernst effect 307
nickel, resistance in 306
optical rotation 297–304
resistance of metals in . . . 306
thermo-magnetic effects . . . 307
Magnetic properties: of cobalt at 100° C . . . 293
iron: hysteresis . 294–296
permeability 286–288, 292–293
saturated . . . 293
weak fields . . 294
magnetite 293
nickel at 100° C . . . 293
Magnetic susceptibility, liquids, gases 305
Magnetic units, conversion formulæ 3
Magnetism, terrestrial: agonic line 115
declination 110
dip 112
horizontal intensity . . 113
inclination 112
intensity, horizontal . . 113
total 114
Magneto-optic rotation 297–304
Masses of the earth and planets 109
alloys 89
elements, liquid and solid 85
solids 88
woods 87
Materials, strength of: bricks 71
concrete 71
metals 71
stones 71
timber 72–73
woods 72–73
Mechanical equivalent of heat 227
Melting-points: chemical elements 209
inorganic compounds 211
mixtures (alloys) 214
(low melting-points) . 214
organic compounds 215
Mercury: density of 97
electric resistance of 262–263
pressure of columns of 116
specific heat 229
vapor pressure 148
Metals: diffusion of, into metals 138
indices of refraction 182
potential differences with solids . . . 256
solutions . . 257
reflection of light by 192
refractive indices 182
resistance, electrical 262–263
specific 263
sheet, weight of 70
Metallic oxides, refractive indices 182
Methyl alcohol, density of aqueous 98
Metric weights and measures: British equiv . 7–10
U. S. equivalents 5–6
Minerals, specific heats of 231
Mixtures, freezing 220
Moduli of elasticity: rigidity 74
Young's 75
Molecular conductivities: equivalent . . 275–278
specific . . . 271–274
Moments of inertia 58
Musical scales 103
Mutual inductance, table for computing . . . 56

Nernst thermo-magnetic difference of potential . 307
Neutral points, thermo-electric 258–259
Newton's rings and scale of colors 198
Nickel: Kerr's constants for 305
magnetic properties of, at 100° C . . . 293
resistance in magnetic field 306
Nitroso-dimethyl-aniline, refractive index . . 184

Ohm, various determinations of 261
legal value 261
Oils, viscosity of 126
Organic compounds, boiling-points 215
densities 215
melting-points 211

Parallax: solar; lunar 109
Peltier effect 258, 260
Pendulum, length of seconds 107
Perfect gas, expansion of 162
volume of 162
Permeabilities, magnetic . . . 286–288, 292–293
Photometric standards 177
Pi, π, value of 12
Planck's radiation formula 238
Plane, data for the soaring of a 123
Planets, miscellaneous data 109
Poisson's ratio 76
Polarized light: by reflection 191
rotation by magnetic field 297–304
solutions 197
Potential difference: cells: double fluid 253
secondary 253
single fluid 252
standard . . . 251, 253
storage 253
contact: liquid-liquid . . 254
liquid-salt . . . 254
metal-liquid . . 257
solid-solid . . . 256
sparking: air . . . 248–249
kerosene . . . 250
various . . . 250
thermoelectric . . . 258–259
Precession 109
Pressure: barometric measures 117–121
barometric and boiling water . . 168–169
heights 107
mercury columns, due to 116
water columns, " " 116
wind 122
Pressure, vapor: alcohol, ethyl and methyl . . 146
aqueous: low temperature . . 151
0° to 100° C . . . 152
100° to 230° C . . 153
in atmosphere . . 155
mercury 148
salt solutions 149
various 144–148
Probability tables 47–48
Purkinje's phenomenon 178

Quartz fibres, strength of 71
refractive index of 185

Radiation: black-body 238
constants of 238
cooling by, and convection . . 239–240
eye, sensitiveness of, to 178
Planck's formula 238
sensitiveness of the eye to 178
"solar constant" of 179
Stefan's formula 238
transmissibility of atmosphere to . 179
Radii of gyration 58
Refraction, indices of: alums 181
crystals 187
fluorite 184
gases and vapors . . . 190
glass 180
Iceland spar 184
liquids 189
metals, metallic oxides . 182
monorefringent solids . 186
nitroso-dimethyl-aniline . 184
quartz 185
rock-salt 183
salt solutions 188
silvine 183
solids, isotropic . . . 186
Reflection of light: by metals 192
terms of "n" and "i" . 191
Relative humidity 158

esistance: *see also* Conductivity.
alloys, low temperature 264
alternating current, effect of . . . 269
electrolytic, *see* Conductivity.
glass and porcelain 285
legal unit of 261
magnetic field, of bismuth in . . . 306
metals in . . . 306
nickel in . . . 306
metals at low temperatures . . . 264
ohm, various determinations of . . 261
specific: metals 263
wires 262
temperature variation . . 262–266, 285
wire (copper) table, common units . 66
metric units . . 68
idity, modulus of 74
temperature variation . . 74
g correction (magnetization) 288
k-salt, indices of refraction 183
is, demagnetizing factors for 289
tation of polarized light: by solutions . . 197
tation, magneto-optic: formulæ 297
gases 304
Kerr's constant . . 305
liquids 299
solids 298
solutions . . . 301–303
Verdet's constant 297–304
vland's standard wave-lengths 171

s, lowering of freezing-point by 217
raising " boiling- " " 219
ıration, magnetic, for steel 293
les, musical 103
sens, color 195–196
onds pendulum 107
ondary batteries 253
tions of wires 59–66
aring tests of timber 72–73
et metal, weights of 70
er, electro-chemical equivalent . . . 251, 270
rine, indices of refraction 183
es, natural and logarithmic, circular . 30–38
hyperbolic . 39–40
-light, comparison with sunlight 179
aring of planes, data for 123
ar constant of radiation 179
energy, data of 179
wave-lengths, Rowland's 171
lids: compressibility 76, 83
densities 85–89
dielectric constant 283
electrical resistance 261–269
hardness 76
indices of refraction 183–187
magneto-optic rotation by 298
thermal conductivity 199
expansion 222–224
olutions: boiling-point, raising by salts in . . 219
boiling-points of aqueous . . . 219
conductivity, thermal 200
electrolytic . . 272–278
densities of aqueous 92–93
diffusion of aqueous 136
freezing-points, lowering by salt . . 217
of aqueous 217
indices of refraction 188
magneto-optic rotation of . . 301–303
potential (contact) differences . 254–257
specific heats 230–231
surface tensions 142
viscosities 129–133
ound, velocity of, in solids 101
liquids and gases . . . 102
parking potentials 248–250
pecific gravity, *see* Density.
heat of air 232
elements 228
gases 232
iron at high temperatures . . 308
liquids 230
mercury 229
minerals and rocks 231
solids 230
vapors 232
water 229
pecific heat of electricity" 258
cific inductive capacity: gases . . . 279–280
liquids . . . 280–282
solids 283
cific molecular conductivities 273–274

Specific resistance 262–263
viscosity: gases and vapors . . . 134–135
liquids and oils . . . 126–128
solutions 129–133
Spectra: elements, brighter lines 170
iron, Fabry-Buisson 170
Kayser 174
solar, Fraunhofer lines 176
Rowland's measures 171
Squares, least, tables 47–49
Standard cells 251–253
wave-lengths: Fabry-Buisson . . . 170
Kayser 174
Rowland 171
Standards, photometric 177
Steam tables: metric units 241
common " 242
Steel: magnetic properties: hysteresis 291, 294–296
permeabilities 286–294
Stefan-Boltzmann radiation formula 238
Stone: strength of 71
thermal conductivity 199
Storage batteries 253
Strength of materials: bricks 71
concrete 71
metals 71
stones 71
timber, woods . . . 72–73
Sun: constant of radiation 179
disk; distribution of intensity 179
light; ratio to sky-light 179
parallax 109
radiation 179
spectrum 171, 179
temperature 179
Surface tension 142–143
Susceptibility, magnetic, liquids and gases . . 305
Sylvine, refractive indices 183

Taylor's series 12
Temperature, critical, for gases 221
resistances for low 264
sun's 179
Tensile strengths 71–73
Tension, surface 142–143
vapor, *see* Vapor pressure.
Terrestrial magnetism: agonic line 115
declination, secular change 110
dip 112
secular change . . . 112
horizontal intensity . . . 113
secular change 113
inclination 112
secular change . 112
total intensity 114
secular change 114
Thermal conductivities: gases 200
liquids 200
salt solutions 200
solids 199
water 200
Thermal expansion: cubical: crystals 224
gases 226
liquids 225
solids 224
linear: elements 222
various 223
Thermal unit, dynamical equivalent 227
Thermo-electricity 258–260
Peltier effect 258, 260
Thermo-magnetic effects 307
Thermometer: air-16, 0° to 300° C 234
59, 100° to 200° C 234
high-temperature-59 . . . 235
hydrogen-16, 0° to 100° C . . . 233
16, 59, −5° to −35° C . 233
59, 0° to 100° C . . . 233
various 235
Thermometer stem correction 236–237
Thomson thermo-electric effect 258
Timber, strength of 72–73
Time, sidereal, solar 108
Transformer-iron, permeability of . . . 286–287
steels, energy losses in . . . 294, 296
Transmissibility to radiation: atmospheric . . 179
crystals 194
glass 193
Trigonometric functions: arguments (° ′) . . . 30
(radians) . 35

United States weights and measures, conversion to metric units 5–6

Units of measurement: definitions, *see* APPENDIX.
conversion factors 2–3
discussion, *see* INTRODUCTION.
photometric 177
ratio of electro-magnetic to static . . . 247

V, ratio of electro-magnetic to -static units . . 247
Vapor, aqueous: vapor pressure, low temp. . . 151
0°–100° C . . 152
100°–230° C . 153
pressure of, in atmosphere . . 155
relative humidity 158
(saturated) weight of 154
Vaporization, latent heat of 206
for steam . . 241, 242
Vapors: densities 91
diffusion of 137, 138
indices of refraction 190
pressures: alcohol, ethyl, methyl . . . 146
aqueous: low temp. . . . 151
0°–100° C . . . 152
100°–230° C . . . 153
mercury 148
salt solutions 149
various 144–148
specific heats 232
viscosity, specific 134
Velocity of light 109
sound; in gases and liquids . . . 102
solids 101
Verdet's constants: Verdet and Kundt's . . . 304
gases 304, 305
liquids 299, 305
solids 298
solutions, alcoholic 303
aqueous 301
hydrochloric . . 303
Viscosity: alcohol in water 126
gases 135
liquids 127
vapors 135
water: temperature variation . . . 125
specific: gases 134
oils 126
solutions 129–133
vapors 134
water: temp. var. 125
Voltaic cells: composition, E. M. F. . . 252–253
double-fluid 253
secondary 253
single-fluid 252
standard 251, 253
storage 253
Volts, legal (international) . . . . . xxxiv, 251
Volumes: critical, for gases 221

Volumes: gases, perfect 162
glass vessels, determinations of . . . 11

Water: boiling-points for various pressures:
common measures 168
metric measures . 169
densities, temperature variation . . 95, 96
ionization of 278
solutions in: boiling-points 219
densities 92
diffusion 136
electrolytic conduction 272–278
solutions of alcohol, densities . . . 98–100
thermal conductivity 200
vapor pressure: low temperatures . . 151
0° to 100° C 152
100° to 230° C . . . 153
vapor, pressure of, in atmosphere . . 155
(saturated) weights of 154
viscosity: absolute, temp. var. . . . 125
specific, temp. var. 125
Wave-lengths: cadmium red line 170
elements, brighter lines . . . 170
Fabry-Buisson iron arc lines . . 170
Fraunhofer lines 176
iron lines, Fabry-Buisson . . . 170
Kayser 174
Kayser's iron arc lines 174
Rowland's solar lines 171
solar lines (Rowland) 171
Weights and measures: British to metric . . 9–10
metric to British . . . 7–8
metric to U. S. . . . 6
U. S. to metric . . . 5
Weights of bodies. 58
Weights of sheet metal 70
wire: copper, iron, brass:
common units 60
metric units . 62
aluminum, common and metric . . 64
copper wire, electrical constants
common units 66
metric units . 68
Wind pressures 222
Wire gauges: Birmingham 59
British standard 59
Brown and Sharp 66
Wire, weights of: brass, copper, iron . . . 60, 62
aluminum 64
copper 66, 68
Woods: densities of 87
strength of 72–73

Young's modulus of elasticity 75

Zonal harmonics 54

SMITHSONIAN MISCELLANEOUS COLLECTIONS

VOLUME 58, NUMBER 2

BLIOGRAPHY OF THE GEOLOGY AND MINERALOGY OF TIN

BY

FRANK L. HESS and EVA HESS

(PUBLICATION 1987)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
1912

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

CONTENTS

PAGE

roduction 1
t of journals and other publications to which reference is made, with abbreviations used 3
Bibliography arranged by countries:
Africa 19
Alabama 21
Alaska 21
Argentine Republic 25
Asia 25
Australia 26
Austria 28
Banka 29
Billiton 34
Bolivia 36
Burmah 45
California 48
Canada 50
Cape Colony 51
Carolina, North and South 52
Ceylon 54
Chili 55
China 55
Colorado 57
Congo 57
East Indies 58
England 61
Europe 84
Finland 84
France 85
French Guiana 89
Georgia 89
Germany 89
Greenland 96
Honduras 97
Idaho 97
India 97
Ireland 98
Italy 100

PAGE
Japan 103
Kamerun 104
Korea 104
Laos 104
Madagascar 105
Maine 105
Malay Peninsula 106
Massachusetts 118
Mexico 119
Michigan 123
Missouri 123
Montana 123
Nevada 123
Newfoundland 123
New Guinea 124
New Hampshire 124
New Jersey 124
New South Wales 124
New Zealand 132
Nigeria 132
North America 133
Northern Territory 133
Norway 134
Perak 134
Persia 134
Peru 134
Philippine Islands 135
Portugal 135
Queensland 136
Russia 144
Santo Domingo 145
Scotland 145
Siam 145
Siberia 146
South America 148
South Australia 148
South Dakota 148
Spain 155
Swaziland 158
Sweden 160
Tasmania 160
Texas 174
Transvaal and Rhodesia 175
United States 179
Victoria 183
Virginia 186

PAGE
Washington 187
Western Australia 187
Wyoming 190
General Bibliography 191
History 203
Metallurgy and Chemistry 209
Mineralogy 226
Mining and Milling 234
Statistics 237
Index (prepared by Lancaster D. Burling) 241

INTRODUCTION

Some years ago when one of the authors of this work was engaged in looking up authorities upon tin deposits, no list of the papers on even such noted occurrences as those of Great Britain, Germany, or the Malay Peninsula was to be found, while it required much effort and continued search to find what had been written upon Bolivia and the lesser known localities.

No monographic work covered the field, for many discoveries and great developments had taken place since the appearance of the only comprehensive book, E. Reyer's "Zinn," in 1880, and his bibliographic references were often indefinite and far from complete. There seemed to be real need for an extensive bibliography, and during five years one or both authors have been engaged a considerable part of the time in the collection and digestion of material for such a publication. Since the work was begun Sydney Fawns' "Tin Deposits of the World" has appeared, but the list of authorities given is not extensive.

Owing to the circumstances under which the work was done the notes upon the papers listed do not consistently follow one plan. Little attempt has been made to digest works in foreign languages. Of those in English, some are digested, some have the contents noted, and, in a few cases, where it conveys a good idea of the matter treated, only the title is given.

In digesting articles upon the geology of tin deposits it has been aimed to give, where possible, (a) the country rocks, (b) age, (c) origin of the deposits, (d) accompanying minerals, (e) economic importance, and (f) other details of value.

When desiring to consult the literature of tin deposits it is believed that as a rule persons will wish to know about the tin-bearing veins, dikes, or placers of a particular country or district, and in the arrangement of this bibliography the works are, where possible, placed under the names of the countries in which are located the tin deposits of which they treat. The names of the countries follow each other in alphabetic order, and under each heading names of authors are in similar order.

Anonymous articles are listed under "Anon." which takes its place in the alphabetic sequence. Where more than one article occurs under "Anon." they are arranged chronologically.

Where deposits in a number of countries are treated in one article, the title is placed under the heading "General."

Works treating preponderantly of the extraction, handling, and reduction of tin ores are placed under "Mining and Milling" and "Metallurgy." The lists given under these subjects are not published with the idea that they are complete and no effort has been made to make them so, but as important articles were met, it seemed best to note them, in the hope that even an incomplete list might be of use to many persons who desire only a certain amount of general knowledge upon the subject. The lists may serve, also, as a nucleus for some who wish to pursue the subject further.

Headings other than "General" and names of countries form a second alphabetic list which follows the list of countries.

In the geological portion of the bibliography it is believed that no important paper upon tin appearing up to the middle of 1908 has been omitted. Following this prefatory note will be found the abbreviations used for journals referred to in the work. The bibliography is classified as follows: I, By Countries; II, General; III, History; IV, Metallurgy and Chemistry; V, Mineralogy; VI, Mining and Milling; VII, Statistics. It is thought that the exhaustive index prepared by Mr. Lancaster D. Burling will supplement the arrangement of articles under countries and make the finding of particular papers comparatively easy.

FRANK L. HESS.
EVA HESS.

F JOURNALS AND OTHER PUBLICATIONS TO WHICH FERENCE IS MADE, WITH ABBREVIATIONS USED

th. phys. Classe kön. bay. Wiss.	Abhandlungen der mathematisch-physikalischen Classe der königlich bayerische Akademie der Wissenschaften, München.
c. sci. Chili	Actes de la Société scientifique du Chili, Santiago.
hem. Journ.	American Chemical Journal, Baltimore.
Geol.	American Geologist, Minneapolis. Incorporated in 1906 with Economic Geology, Lancaster, Pa.
nst. Mg. Eng.	American Institute of Mining Engineers, New York.
	Transactions of the American Institute of Mining Engineers, New York.
	Bulletin of the American Institute of Mining Engineers, New York.
	Bi-monthly Bulletin of the American Institute of Mining Engineers, New York.
urn. Sci. Arts	American Journal of Science and Arts, New Haven. American Journal of Science after Vol. 19, 1880.
ourn. Mg. Mill. Oilb. Geol. Met.	American Journal of Mining, Milling, Oilboring, Geology, Mineralogy, Metallurgy, New York. In 1866 title changed to Engineering and Mining Journal, New York.
fr. Iron World	American Manufacturer and Iron World, Pittsburg.
lg. Rev.	American Mining Review (now Mining Review), Los Angeles.
hilos. Soc.	Proceedings of the American Philosophical Society, Philadelphia.
it. Geol.	Annals of British Geology. By J. F. Blake, London.
hem. Pharm.	Annalen der Chemie und Pharmacie, Heidelberg.

Ann. Chim. Phys.	Annales de Chimie et de Physique, Paris.
Ann. Gén. Civ.	Annales du Génie Civil, Paris.
Ann. Indust. nat. étr.	Annales de l'Industrie nationale et étrangère, Paris.
Ann. Mines.	Annales des Mines, Paris.
Ann. New York Acad. Sci.	Annals of New York Academy of Sciences, New York.
Ann. Philos. Mag. Chem. Min. Mech. Nat. Hist. Agr. Arts.	Annals of Philosophy or Magazine of Chemistry, Mineralogy, Mechanics, Natural History, Agriculture and the Arts, London.
Ann. Philos.	Annals of Philosophy, London.
Ann. Physik. Chem.	Annalen der Physik und Chemie, by Julius C. Poggendorff, Leipzig.
Ann. Progr. Rep. Geol. Surv. Western Australia.	Annual Progress Report of the Geological Survey of Western Australia, Perth.
Ann. Rep. Board Reg. Smithsonian Institution.	Annual Report of the Board of Regents of the Smithsonian Institution, Washington, D. C.
Ann. Rep. California State Min.	Annual Report of the California State Mineralogist, Sacramento.
Ann. Rep. Dep. Mines, New South Wales.	Annual Report Department of Mines, New South Wales, Sydney.
Ann. Rep. Dir. U. S. Geol. Surv.	Annual Report of the Director of the United States Geological Survey, Washington, D. C.
Ann. Rep. Geol. Surv. Canada.	Annual Report of the Geological Survey of Canada, Ottawa.
Ann. Rep. Geol. Surv. Texas.	Annual Report of the Geological Survey of Texas, Austin.
Ann. Rep. Roy. Cornwall Polyt. Soc.	Annual Report of the Royal Cornwall Polytechnic Society, Falmouth.
Ann. Rep. Roy. Inst. Cornwall.	Annual Report of the Royal Institution of Cornwall, Truro.
Ann. Rep. School Mines Zeehan.	Annual Report of the School of Mines Zeehan, Zeehan, Tasmania.
Ann. Rep. Secr. Mines Water Supply.	Annual Report of the Secretary for Mines and Water Supply, Melbourne.
Ann. Rep. Trans. Plymouth Inst. Devon and Cornwall Nat. Hist. Soc.	Annual Report and Transactions of the Plymouth Institution and Devon and Cornwall Natural History Society, Plymouth.
Ann. Rep. Under-Secretary for Mines, Queensland.	Annual Report of the Under-Secretary for Mines, Queensland, Brisbane.

Sci. Nat.....Annales des Sciences Naturelles, Paris.
Soc. géol. Belg.....Annales de la Société géologique de Belgique, Liége.
Voy.....Annales des Voyages, etc., Paris. Title changes: Nouvelles Annales des Voyages et des Sciences Geographique, Paris.
Bergb. Hütt.....Archiv für Bergbau und Hüttenwesen. By C. J. B. Karsten, Breslau und Berlin. Title changes: Archiv für Mineralogie, Geognosie, Bergbau und Hüttenkunde.
Miner. Geogn. Bergb. Hütt.....Archiv für Mineralogie, Geognosie, Bergbau und Hüttenkunde. By C. J. B. Karsten und H. v. Dechen, Berlin. See also Arch. Bergb. Hütt.
Miss. sci. litt.....Archives des Missions scientifiques et littéraires, Paris.
R. Accad. Lincei. (Trans. or m.) Atti della Reale Accademia dei Lincei (Transunti or Memorie), Roma.
nd. .....Das Ausland, Stuttgart und München.
. Ass. Adv. Sci.....Australasian Association for the Advancement of Science, Sydney.
. Mg. Eng. Rev.....Australian Mining and Engineering Review, Melbourne and Sydney.
. Mg. Stand.....Australian Mining Standard, Sydney and Melbourne.
Hütt. Zeit.....Berg- und hüttenmännische Zeitung, Leipzig.
. Bull. Amer. Inst. Mg. Eng.....Bi-monthly Bulletin of the American Institute of Mining Engineers, New York.
om. Mapa Geol. España.....Boletin de la Comision del Mapa Geologico de España, Madrid.
Inst. Geol. Mexico.....Boletin del Instituto Geológico de México, Mexico.
lin. Indust. Constr.....Boletin de Minas Industria y Construcciones, Lima.
R. Com. geol. Italia.....Bollettino Reale Comitato geologico d'Italia, Roma.
Secr. Fom.....Boletín de la Secretaría de Fomento, Mexico.
Soc. esp. Hist. Nat.....Boletin de la Sociedad española de Historia Natural, Madrid.
Soc. Ing.....Boletin de la Sociedad de Ingenieros, Lima, Peru.

Bol. Soc. Nac. Min.....Boletin de la Sociedad Nacional Minería, Lima.

British Columbia Mg. Rec.....British Columbia Mining Record, Victoria.

Brit. Mfr. Indust.....British Manufacturing Industries. Edited by G. Phillips Beven, London.

Bull. Imp. Inst. Great Britain.....Bulletin of the Imperial Institute of Great Britain, London.

Bull. Inst. Mg. Met.....Bulletin of the Institution of Mining and Metallurgy, London.

Bull. Geol. Surv. Alabama.....Bulletin of the Geological Survey of Alabama, Montgomery.

Bull. Mines Indust. or.....Bulletin des Mines et de l'Industrie de l'or, Tomsk.

Bull. North Carolina Geol. Surv.....North Carolina Geological Survey, Bulletin, Raleigh.

Bull. Soc. belge Géol. Pal. Hydr.....Bulletin de la Société belge de Géologie de Paléontologie & d'Hydrologie, Bruxelles.

Bull. Soc. franç. Min.....Bulletin de la Société française de Minéralogie, Paris.

Bull. Soc. Géogr.....Bulletin de la Société de Géographie, Paris.

Bull. Soc. géol. Belgique.....Bulletin de la Société géologique de Belgique, Liége.

Bull. Soc. géol. France.....Bulletin de la Société géologique de France, Paris.

Bull. Soc. Hist. nat. Toulouse.....Bulletin de la Société d'Histoire naturelle de Toulouse, Toulouse.

Bull. Soc. Indust. min.....Bulletin de la Société de l'Industrie minérale, Saint-Etienne.

Bull. Soc. sci. méd. Ouest.....Bulletin Société scientifique et médicale de l'Ouest, Rennes.

Bull. South Dakota Geol. Surv.....South Dakota Geological Survey Bulletin, Vermillion.

Bull. U. S. Geol. Geogr. Surv. Terr....Bulletin of the United States Geological and Geographical Survey of the Territories, F. V. Hayden, U. S. Geologist-in-charge, Washington, D.C.

Bull. Western Australia Geol. Surv....Western Australia Geological Survey Bulletin, Perth.

Calcutta Journ. Nat. Hist.....Calcutta Journal of Natural History, by McClelland, Calcutta.

California Journ. Techn. .....California Journal of Technology, Berkeley.

Can. Mg. Rev.....The Canadian Mining Review, Montreal.

m. Abs. ..... Chemical Abstracts, Easton, Pa.
m. Engr. ..... The Chemical Engineer, Chicago.
m. Gaz. ..... Chemical Gazette, London.
m. News. ..... Chemical News, London.
. Guard. ..... Colliery Guardian, London.
ac. Indust. ..... Ciencia é Industrias, Buenos Aires.
R. Acad. Sci. ..... Comptes Rendus de l'Académie des Sciences, Paris.
. Mines Geol. Surv., New South Wales. — Department of Mines, Geological Survey of New South Wales, Sydney.
lin Univers. Mag. ..... Dublin University Magazine, Dublin.
o des Mines ..... Echo des Mines, Saint Étienne.
n. Geol. ..... Economic Geology with which is incorporated the *American Geologist*, Lancaster, Pa.
nburgh New Philos. Journ. ..... Edinburgh New Philosophical Journal, Edinburgh.
tr. Eng. ..... Electrical Engineer, New York.
ineer. ..... The Engineer, London.
ineering. ..... Engineering, London.
. Mag. ..... Engineering Magazine, New York and London.
. Mg. Journ. ..... Engineering and Mining Journal, New York. See American Journal of Mining, Milling, Oilboring, Geology, Mineralogy, Metallurgy.
. News Amer. Railw. Journ. ..... Engineering News and American Railway Journal, New York.
geol. Specialkarte Kön. Sachsen. — Erläuterungen zur geologischen Specialkarte des Königreichs Sachsen, Leipzig.
l. Centr. ..... Geologisches Centralblatt, Leipzig.
l. För. Stockholm Förh. ..... Geologiska Föreningens i Stockholm Förhandlingar, Stockholm.
l. Mag. ..... Geological Magazine, London.
l. Minas. ..... Geología y Minas, Buenos Aires. Title changed in 1909 to Ciencia é Industrias.
l. Rec. ..... The Geological Record. Edited by Wm. Whitaker, London.
. Nat. Freunde Berlin Mag. neuest. ntd. Ges. Nat. — Der Gesellschaft naturforschender Freunde zu Berlin Magazin für die neuesten Entdeckungen in der Gesammten Naturkunde, Berlin.
n. Sci. ..... Gleanings in Science, Calcutta.

Glück. Berg. hütt. Zeit. Nied. Westph. Glückauf; Berg- und hüttenmännische Zeitung für den Niederrhein und Westphalen, Essen (Ruhr.).

Illustration .....L'Illustration, Journal universel, Paris.

Imp. Inst. Tech. Rep. and Sci. Papers. Imperial Institute Technical Report and Scientific Papers, London.

Ind. Eng.....Indian Engineering, Calcutta.

Indust. Iron.....Industries and Iron, London. Formerly Iron, the Journal of Science, Metals and Manufactures, London.

Institut .....L'Institut Journal des sciences et des Sociétés savantes en France et à l'étranger, Paris.

Iron .....Iron. The Journal of Science, Metals and Manufactures. Continued from 1893 as *Industries and Iron*, a Journal for the Engineering, Electrical, Chemical and Metallurgical Trades, London.

Iron Age.....Iron Age, New York.

Jaarb. Mijnw. Ned. Oost-Indië.....Jaarboek van het Mijnwezen in Nederlandsch Oost-Indië, Amsterdam.

Jahrb. Berg. Hütt. Kön. Sachsen.....Jahrbuch für das Berg- und Hüttenwesen im Königreiche Sachsen, Freiberg.

Jahrb. k. k. geol. Reichs.....Jahrbuch der kaiserlich-königlichen geologischen Reichsanstalt, Wien.

Jahrb. Min. Geogn. Geol. Petr.....Jahrbuch für Mineralogie, Geognosie, Geologie und Petrefactenkunde; von Leonhard Heidelberg. For later series see Neues Jarbuch für Mineralogie, Stuttgart.

Jahr. Chem.....Jahresbericht über die Fortschritte der Chemie und verwandter Theile anderer Wissenschaften, Giessen.

Jern-Kont. Ann.....Jern-Kontorets Annaler, Stockholm.

Journ. Appl. Sci.....Journal of Applied Science, London.

Journ. Asiat. Soc. Bengal.....Journal of the Asiatic Society of Bengal, Calcutta.

Journ. Bath West England Soc.....Journal of Bath and the West of England Society (and Southern Counties Association for the Encouragement of Agriculture, Arts, Manufacture and Commerce), Bath.

hem. Met. Min. Soc. South — Journal of the Chemical, Metallurgical and Mineralogical Society of South Africa, Johannesburg.

iem. Soc. London..... Journal of the Chemical Society of London. Formerly Quarterly Journal of the Chemical Society.

llege Sci. Imp. Univers. — Journal of the College of Science of the Imperial University, Tokyo.

lisha Mitchell Sci. Soc. ..... Journal of the Elisha Mitchell Scientific Society, Raleigh.

ranklin Inst..... Journal of the Franklin Institute, Philadelphia.

eol..... Journal of Geology, Chicago.

eol. Soc. Dublin..... Journal of the Geological Society of Dublin, Dublin.

dian Arch. East Asia..... Journal of the Indian Archipelago and Eastern Asia, Singapore.

lines..... Journal des Mines, Paris.

at. Philos. Chem. Arts..... Journal of Natural Philosophy, Chemistry and the Arts, London.

harm..... Journal de Pharmacie (et des Sciences accessoires contenant le Bulletin des Travaux de la Société de Pharmacie de Paris), Paris.

akt. Chem..... Journal für praktische Chemie. Otto Linne Erdmann, Leipzig.

int. Pap. Parl. Tasmania.... Journal and Printed Papers of the Parliament of Tasmania, Hobart.

oc. Roy. Soc., New South — Journal and Proceedings of the Royal Society of New South Wales, Sydney.

y. Geol. Soc. Ireland..... Journal of the Royal Geological Society of Ireland. London, Dublin and Edinburgh.

y. Inst. Cornwall..... Journal of the Royal Institution of Cornwall, Truro.

c. Arts..... Journal of the Society of Arts, London.

raits Branch Roy. Asiatic — Journal of the Straits Branch of the Royal Asiatic Society, Singapore.

Tijdschr. Ned.-Indië..... Koninklijk Natuurkundig Tijdschrift van Nederlandsch-Indië, Batavia.

ved. Akad. Wiss. Abh. Nat. Mech. — Königlich Schwedische Akademie der Wissenschaften Abhandlungen aus der Naturlehre, Haushaltungskunst und Mechanik, Leipzig.

..... La Nature, Paris.

London, Edinburgh, Dublin Philos. Mag. Journ. Sci.	London, Edinburgh and Dublin Philosophical Magazine and Journal of Science, London.
London and Edinburgh Philos. Mag. Journ. Sci.	London and Edinburgh Philosophical Magazine and Journal of Science, London.
"Lotos" Zeitschr. Nat.	"Lotos," Zeitschrift für Naturwissenschaften, Prag.
Mech. Eng.	The Mechanical Engineer, London.
Mech. Mag.	Mechanics' Magazine, London.
Medd. Grönl.	Meddelelser om Grönland, Kjøbenhavn.
Mem. descr. Carta Geol. Italia.	Memorie descrittive della Carta Geologica d'Italia, Roma.
Mem. Com. Mapa Geol. España.	Memoria de la Comision del Mapa Geologico de España, Madrid.
Mem. Geol. Surv. Great Britain.	Memoirs of the Geological Survey of Great Britain, London.
Mem. Geol. Surv. New South Wales.	Memoirs of the Geological Survey New South Wales, Sydney.
Mem. Geol. Surv. Summ. Progr. Geol. Surv. United Kingdom and Mus. Pract. Geol.	Memoirs of the Geological Survey, Summary of Progress of the Geological Survey of the United Kingdom and Museum of Practical Geology, London.
Mem. Soc. Sci. Nat. Arch. Creuse.	Memoires de la Société des Sciences Naturelles et Archéologiques de la Creuse, Guéret.
Métallurgie	La Métallurgie, Paris.
Mex. Mg. Journ.	Mexican Mining Journal, Mexico.
Mg. Alm.	Mining Almanack, London.
Mg. Ass. Inst. Cornwall.	Mining Association and Institute of Cornwall, Truro. Report and Proceedings of Miners' Association and Institute of Cornwall, Truro.
	Transactions of the Mining Association and Institute of Cornwall, Camborne.
Mg. Journ. Railw. Comm. Gaz.	Mining Journal, Railway and Commercial Gazette, London.
Mg. Mag.	Mining Magazine, New York.
Mg. Mag.	Mining Magazine, London.
Mg. Rec., British Columbia.	British Columbia Mining Record, Victoria.
Mg. Rep.	Mining Reporter, Denver, Colo.
Mg. Rev.	Mining Review, Los Angeles. See also American Mining Review.

Sci.	Mining Science, Denver.
Sci. Press	Mining and Scientific Press, San Francisco.
Smelt. Mag. Mo. Rev. Pract. ;. Quarry. Met.	London Mining and Smelting Magazine, a Monthly Review of Practical Mining, Quarrying, and Metallurgy, etc., H. C. Salmon, editor.
World.	Mining World, Chicago.
World Eng. Rec.	Mining World and Engineering Record, London.
s and Min.	Mines and Minerals, Scranton, Pa.
Ind.	Mineral Industry, New York and London.
Mag. Journ. Min. Soc.	Mineralogical Magazine and Journal of the Mineralogical Society, London.
Mitth.	Mineralogische Mittheilungen, von G. Tschermak, Wien.
Proc. Inst. Civ. Eng.	Minutes of Proceedings of the Institution of Civil Engineers, London.
Rep.	Mining Reporter, Denver.
Res. U. S. Geol. Sur.	Mineral Resources of United States, published annually by the U. S. Geological Survey, since 1883.
Surv. Ceylon Adm. Rep.	Mineralogical Survey, Ceylon, Administration Reports, Colombo.
h. Jahrb. kön. ung. geol. Anst.	Mittheilungen aus dem Jahrbuche der königlich ungarischen geologischen Anstalt, Budapest.
h. k. k. Techn. Gewerbe-Museums Wien.	Mittheilungen des kaiserlich-königlichen Technologischen Gewerbe-Museums in Wien.
atsb. deutsch. geol. Ges.	Monatsberichte der deutschen geologische Gesellschaft, Berlin.
ogr. U. S. Geol. Surv.	Monographs of the United States Geological Survey, Washington, D. C.
Bull. Int. Bur. Amer. Repub.	Monthly Bulletin of the International Bureau of American Republics, Washington, D. C.
Hist. Journ. School Rep.	Natural History Journal and School Reporter, York.
ire.	Nature, London.
es Jahrb. Min.	Neues Jahrbuch für Mineralogie, Stuttgart. For earlier series see Jahrbuch für Mineralogie, Geognosie, Geologie und Petrefactenkunde; von Leonhard, Heidelberg.

North Carolina Geol. Surv. Bull.	North Carolina Geological Survey, Bulletin, Raleigh.
Northwest Mg. Journ.	Northwest Mining Journal, Seattle.
Not. Indian Archipelago Adj. Countr.	Notices of the Indian Archipelago and Adjacent Countries. By J. H. Moor, Singapore.
Nouv. Ann. Voy. Sci. géogr.	Nouvelles Annales des Voyages et des Sciences géographiques, Paris. Formerly Annales des Voyages, Paris.
Oest. Zeitschr. Berg. Hütt.	Oesterreichische Zeitschrift für Berg- und Hüttenwesen, Wien.
Pap. Proc. Roy. Soc. Tasmania.	Papers and Proceedings of the Royal Society of Tasmania, Hobart.
Pap. Proc. Roy. Soc. Van Diemen's Land.	Papers and Proceedings of the Royal Society of Van Diemen's Land, Tasmania.
Parl. Pap.	Parliamentary Papers, London.
Perak Gov. Gaz.	Perak Government Gazette, Kuala Lumpur, Federated Malay States.
Perak Mus. Notes.	Perak Museum Notes, Taiping.
Petermanns Mitth.	Dr. A. Petermanns Mittheilungen aus Justus Perthes' Geographischer Anstalt, Gotha.
Philos. Mag.	The Philosophical Magazine, London.
Philos. Trans. Roy. Soc. London.	Philosophical Transactions of the Royal Society of London, London.
Polyt. Centr.	Polytechnische Centralhalle, Leipzig.
Polyt. Journ.	Polytechnische Journal, Dingler, Stuttgart.
Pop. Sci. Mo.	Popular Science Monthly, New York.
Proc. Amer. Mg. Cong.	Proceeding of the American Mining Congress, Denver.
Proc. Amer. Philos. Soc.	Proceedings of the American Philosophical Society, Philadelphia.
Proc. Boston Soc. Nat. Hist.	Proceedings of the Boston Society Natural History, Boston.
Proc. Chem. Met. Soc. South Africa.	The Proceedings of the Chemical and Metallurgical Society of South Africa, Johannesburg. Title changed with Vol. 3, May, 1902, to Proceedings of the Chemical, Metallurgical and Mining Society of South Africa.
Proc. Chem. Met. Min. Soc. South Africa.	The Proceedings of the Chemical Metallurgical and Mining Society of South Africa, Johannesburg.

Proc. Colorado Sci. Soc.....Proceedings of the Colorado Scientific Society, Denver.

Proc. Geol. Soc. London.....Proceedings of the Geological Society of London, London.

Proc. Geol. Ass.....Proceedings of the Geologists' Association, London.

Proc. Inst. Civ. Eng.....Proceedings Institution of Civil Engineers, London.

Proc. Inst. Mech. Eng.....Proceedings of the Institution of Mechanical Engineers, Birmingham.

Proc. Liverpool Geol. Soc.....Proceedings of Liverpool Geological Society, Liverpool.

Proc. Linn. Soc. New South Wales....Proceedings of the Linnean Society of New South Wales, Sydney.

Proc. Roy. Soc. London.....Proceedings of the Royal Society of London, London.

Prog. Min. Ind. Tasmania.....The progress of the Mineral Industry of Tasmania, Hobart.

Prog. Rep. Geol. Surv. Victoria.....Progress Report Geological Survey of Victoria, Melbourne.

Quart. Journ. Geol. Soc. London.....Quarterly Journal of Geological Society of London, London.

Quart. Mg. Rev.....Quarterly Mining Review, London.

Queensland Gov. Mg. Journ.....Queensland Government Mining Journal, Brisbane.

Rec. Geol. Surv. India.....Records of the Geological Survey of India, Calcutta.

Rec. Geol. Surv. New South Wales.....Records of Geological Survey of New South Wales, Sydney.

Rec. Geol. Surv. South Victoria.....Records of Geological Survey, South Victoria, Melbourne.

Rec. Mines South Australia.....Record of the Mines of South Australia, Adelaide.

Rep. Brit. Ass. Adv. Sci.....Report of the British Association for the Advancement of Science, London.

Rep. California State Mg. Bur.....Report of California State Mining Bureau, Sacramento.

Rep. Dep. Min. Western Australia....Report of the Department of Mines of Western Australia, Perth.

Rep. Insp. Mines.....Reports of the Inspectors of Mines to Her Majesty's Secretary of State, London.

Rep. Proc., Min. Ass. Cornwall and Devon. Report and Proceedings of Miners' Association of Cornwall and Devon, Truro. Now Mining Association and Institute of Cornwall, Falmouth.

Rep. Roy. Inst. Cornwall.....Report of the Royal Institution of Cornwall, Truro.

Rep. Roy. Cornwall Polyt. Soc.....Report on the Royal Cornwall Polytechnic Society, Falmouth.

Rep. Rugby School Nat. Hist. Soc.....Report of the Rugby School Natural History Society, Rugby.

Report Secretary of the Immigration Commission, to the Finance Minister of the Province, No. 119, Buenos Aires.

Rep. Secr. Mines Tasmania.....Report of the Secretary for Mines, Tasmania, Hobart.

Rep. South African Ass. Adv. Sci.....Report of the South African Association for the Advancement of Science, Cape Town.

Rev. Min.....Revista Minera, Madrid.

Rev. Univ. Mines Mét. Trav. Publ. Sci. Arts Appl. Indust. Revue Universelle des Mines, de la Métallurgie, des Travaux Publics, des Sciences et des Arts Appliquées à l'Industrie, Liége and Paris.

School Mines Quart.....School of Mines Quarterly, New York.

Science. .....Science, New York.

Sci. Amer. Suppl.....Scientific American Supplement, New York.

Sci. Proc. Roy. Dublin Soc.....Scientific Proceedings of the Royal Dublin Society, Dublin.

Sel. Rec. Bengal Gov.....Selections from the Records of the Bengal Government, Calcutta.

Sel. Rec. Gov. India.....Selections from the Records of the Government of India, Public Works Department, Calcutta.

Sitz. Kön. bayer. Akad. Wiss.....Sitzungsberichte der Königlich bayerischen Akademie der Wissenschaften, München.

Sitz. Nat. Ges.....Sitzungsberichte der Naturforschenden Gesellschaft, Leipzig.

Sitz. Abh. Nat. Ges. "Isis."....Sitzungsberichte und Abhandlungen der Naturwissenschaftlichen Gesellschaft "Isis," Dresden.

South African Mg. Journ.....South African Mining Journal, Johannesburg.

South African Mg. Rev.....South African Mining Review.

South African Mines.....South African Mines, Johannesburg.

South Dakota Geol. Surv. Bull.....South Dakota Geological Survey Bulletin, Vermillion.

Spec. Pub. U. S. Geol. Surv.....Special Publication United States Geological Survey, Washington, D. C.

Special Report Department of Mines, Melbourne, Victoria.

Summ. Progr. Geol. Surv. United Kingdom. Summary of Progress of the Geological Survey of the United Kingdom, London.

Summ. Rep. Geol. Surv. Dep. Canada. Summary Report of the Geological Survey Department of Canada, Ottawa.

Tasch. ges. Min. Taschenbuch für die gesammte Mineralogie. Dr. Karl Leonhard, Frankfurt-am-Main. Zeitschrift für Mineralogie, Dr. Karl Leonhard, Heidelberg.

Tasm. Parl. Pap. Tasmanian Parliamentary Papers, Hobart.

Techn. Quart. Technology Quarterly, Boston.

Tijdschr. Ned. Ind. Tijdschrift voor Nederlandsch—Indië; door van Hoëvell, etc., Batavia.

Times Eng. Suppl. London. Times Engineering Supplement, London.

Trans. Amer. Inst. Mg. Eng. Transactions of the American Institute of Mining Engineers, New York. (General.)

Trans. Austr. Inst. Mg. Eng. Transactions of the Australian Institute of Mining Engineers, Melbourne.

Trans. Cornwall and Devon Min. Ass. Transactions Cornwall and Devon Miners' Association, Camborne.

Trans. Devonshire Ass. Adv. Sci. Lit. Art. Transactions of the Devonshire Association for the Advancement of Science, Literature and Art, Plymouth.

Trans. Dublin Soc. Transactions of the Dublin Society, Dublin.

Trans. Fed. Inst. Mg. Eng. Transactions of the Federated Institution of Mining Engineers, Newcastle-upon-Tyne, and London.

Trans. Geol. Soc. Glasgow. Transactions of the Geological Society of Glasgow, Glasgow.

Trans. Geol. Soc. London. Transactions of the Geological Society of London, London.

Trans. Geol. Soc. South Africa. Transactions of the Geological Society of South Africa, Johannesburg.

Trans. Inst. Mg. Eng. Transactions of the Institution of Mining Engineers, London and Newcastle-upon-Tyne. See also Transactions of the Federated Institution Mining Engineers.

Trans. Inst. Mg. Met. Transactions of the Institution of Mining and Metallurgy, London.

Trans. Manchester Geol. Soc.....Transactions of the Manchester Geological Society, Manchester.

Trans. Mg. Ass. Inst. Cornwall.....Transactions of the Mining Association and Institute of Cornwall, Camborne.

Trans. North of England Inst. Mg. Mech. Eng. Transactions of the North of England Institute of Mining and Mechanical Engineers, Newcastle-upon-Tyne.

Trans. New York Acad. Sci.....Transactions of the New York Academy of Sciences, New York.

Trans. Proc. Roy. Soc. New South Wales. Transactions and Proceedings of the Royal Society of New South Wales, Sydney.

Trans. Roy. Geol. Soc. Cornwall.....Transactions of the Royal Geological Society of Cornwall, Penzance.

Transvaal Mines Dep. Rep. Geol. Surv. Transvaal Mines Department, Report of the Geological Survey, Pretoria.

Trav. Sci. Univ. Rennes.....Travaux Scientifiques de l'Université de Rennes, Rennes.

U. S. Geol. Surv.....United States Geological Survey, Washington, D. C.

For publications of, see Ann. Rep. Dir. U. S. Geol. Surv.; Monogr. U. S. Geol. Surv.; U. S. Geol. Surv. Prof. Pap.; U. S. Geol. Surv. Bull.; U. S. Geol. Surv. Min. Res. U. S. Cal. Year; Spec. Publ. U. S. Geol. Surv.

U. S. Geol. Surv. Bull.....United States Geological Survey Bulletin, Washington, D. C.

U. S. Geol. Surv. Min. Res. U. S. Cal. Year. United States Geological Survey, Mineral Resources of the United States. Calendar Year, Washington, D. C.

U. S. Geol. Surv. Prof. Pap.....United States Geological Survey, Professional Paper, Washington, D. C.

Verh. k. k. geol. Reichs.....Verhandlungen der kaiserlich-königlichen geologischen Reichsanstalt, Wien.

Verh. nat. Ver. preuss. Rheinl. Westph. Verhandlungen des naturhistorischen Vereins der preussischen Rheinlande, und Westphalens, und des Regierungs-Bezirks Osnabrück. Bonn.

Verh. russ. kais. min. Ges.....Verhandlungen der russisch-kaiserlichen mineralogischen Gesellschaft, St. Petersburg.

Vid. Medd. nat. Foren. Kjøbenhavn....Videnskabelige Meddelelser fra den naturhistoriske Forening i Kjøbenhavn. Kjøbenhavn.

Virginias.....The Virginias, Staunton, Va.
Western Australia Geol. Surv. Bull...Western Australia Geological Survey Bulletin, Perth.
Zeitschr. Anorg. Chem.....Zeitschrift für Anorganische Chemie, München und Leipzig.
Zeitschr. Berg. Hütt. Sal. preuss. Sta..Zeitschrift für das Berg- Hütten- und Salinenwesen in dem preussischen Staate, Berlin.
Zeitschr. deutsch. geol. Ges. .....Zeitschrift der deutschen geologischen Gesellschaft, Berlin.
Zeitschr. Kryst. Min.....Zeitschrift für Krystallographie und Mineralogie, Leipzig.
Zeitschr. Min.....Zeitschrift für Mineralogie, by K. C. von Leonhard, Frankfurt-am-Main.
Zeitschr. prakt. Geol.....Zeitschrift für praktische Geologie, Berlin.

BLIOGRAPHY OF THE GEOLOGY AND MINERALOGY OF TIN[1]

BY

FRANK L. HESS AND EVA HESS

BIBLIOGRAPHY ARRANGED BY COUNTRIES

AFRICA

CK, R. **Einige Bemerkungen über afrikanische Erzlagerstätten.**

Zeitschr. prakt. Geol., Vol. 14, 1906, Berlin, pp. 205-208. 2 figs. of rock sections. The tin deposits of South Africa are treated.

BSON, WALCOT. **The geology of Africa in relation to its mineral wealth.**

Trans. Fed. Inst. Mg. Eng., Vol. 12, 1896-97, Newcastle-upon-Tyne and London, p. 307.

Tin merely mentioned as reported in metamorphic areas of South Africa.

OHNSON, J. P. **The ore deposits of South Africa. Part 1, Base metals.**

1908, London, pp. 30-37.

Describes briefly the Rooiberg, Weynek, Doornhoek, Potgietersrust, Welbeloond, Embabaan, and Langerwacht tin deposits.

UNAY, L. DE. **Les richesses minerales de l'Afrique.**

1903, Paris, pp. 158-160.

Tin is found on the Benoue, an affluent of the Niger. In the French Congo it is found in the Crystal Mountains, on the Oubanghi and Ouelle Makua, also at Massinga (or Massinda) north of the village of Agapata in the upper basin of the Banghi in a region of Archæan rocks and granite with copper.

In the northeast part of Swaziland near the frontier of the Transvaal, tin has been known for a long time. Deposits at Embabaan only are promising. Though tin veins are present, only the alluvials have been worked.

There has been the following production:

Year	1894	1895	1896	1897	1898
Tons	143	250	240	70	53

According to Dr. Molengraaff the region is one of mica, talc, chlorite, and amphibolite schists with some quartzites carrying magnetite, similar to the formation at Hospital Hill, Johannesburg. The cassiterite is found, not in the quartz, but in the pegmatite cutting the schists.

OUIS, HENRY. *See* No. 1340.

ECKNAGEL, R. **On the origin of the South African tin deposits.**

Trans. Geol. Soc. South Africa, Vol. 12, 1909, Johannesburg, pp. 168-202.

Review: South African Mg. Journ., Vol. 7, pt. 2, 1909, Johannesburg, pp. 69-70, 111-112.

[1] It is believed that no important paper upon the geology or mineralogy of tin appearing up to the middle of 1908 has been omitted from this bibliography.

ALABAMA

4. ANONYMOUS. Tin in Alabama.

Eng. Mg. Journ., Vol. 34, 1882, New York, p. 309.

A communication in which the writer is very hopeful of tin in paying quantities in Alabama.

5. BENEDICT, WM. DE L. Tin in Alabama.

Min. Ind. for 1892, Vol. 1, 1893, New York, pp. 456-457.

Tin is found near Ashland, Clay County. The ore occurs both in lodes and as stream tin, and is reported to exist in considerable quantities. Metal produced from the ore seems to have been a mixture of iron and tin. Work began at the Broad Arrow mines March 1, 1883, but operations do not seem to have been successful, for in July of same year work was stopped.

6. PHILLIPS, WM. B. Occurrence of tin.

Bull. 3, Geol. Surv. Alabama, 1892, Montgomery, pp. 27-30.

Author describes his visit and examination of the tin of Coosa County, Alabama. Crystals sent to A. R. Ledoux & Co., New York, assayed 78.19 per cent tin.

ALASKA

7. ADAIR, JAMES B. Tin deposits of the York region, Alaska, and what development shows for the season of 1905.

Northwest Mg. Journ., Vol. 1, No. 3, 1906, Seattle, pp. 3-5.

U. S. Geol. Surv. reports on the York tin region for 1904 are quoted and from these the results of the development during the season of 1905, are given.

8. ANONYMOUS. Tin in Alaska.

Min. Ind. for 1901, Vol. 10, 1902, New York and London, p. 638.

Buhner Creek and Anikovik River are mentioned as localities where tin has been found. In the first locality stream tin has been concentrated on the bed rock with small amounts of magnetite, limonite, pyrite, fluorite, garnet, and gold.

9. ———. Tin mining in Alaska.

Eng. Mg. Journ., Vol. 76, 1903, New York, pp. 879-880, 150 words.

Brief mention of the discovery of tin in the Lost River district.

10. ———. Alaskan tin production.

British Columbia Mg. Rec., Vol. XI, No. 12, December, 1904, Victoria, p. 434, 300 words.

"Prospects of the industry discussed."

11. ———. Tin in Alaska.

Eng. Mg. Journ., Vol. 80, 1905, New York, p. 198, 150 words.

The discovery of tin on Seward Peninsula is very briefly mentioned.

12. ———. Alaska.

Mg. World, Vol. 26, 1907, Chicago, p. 154.

The tin outlook in Alaska, which author seems to think good, is discussed.

12a. ———. Tin in Alaska.

Mg. Sci., Vol. 59, 1909, Denver, p. 428.

General.

12b. ———. Mining in United States during 1908.

Eng. Mg. Journ., Vol. 87, 1909, New York, pp. 101-102.

Brief description of manner of occurrence of Alaskan tin.

ALASKA (Continued)

12c. ———. **Tin deposits of Alaska.**

Mg. Journ., Railw. Comm. Gaz., Vol. 85, 1909, London, pp. 607-608.

Describes the manner in which tin occurs at Ears Mountain, Buck Creek, Cape Mountain and Lost River.

ANONYMOUS. *See* T———.

13. BEALES, R. L. **Tin in Alaska.**

Mg. Sci. Press, Vol. 89, 1904, San Francisco, pp. 395-396, illus. 3, 1050 words.

Describes the occurrence of tin on Seward Peninsula; on Cape Prince of Wales, Buck Creek, and Lost River. Describes present method of working.

14. BELL, ROBERT M. **Tin ledges in Alaska.**

Eng. Mg. Journ., Vol. 76, 1903, New York, p. 820, 750 words.

Describes the discovery of ledges containing tin ore in the vicinity of Port Clarence, Alaska.

15. ———. **Tin in Alaska.**

Mg. Sci. Press, Vol. 87, 1903, San Francisco, p. 351.

Describes the occurrence of tin deposits. Since 1899 placer gold has been found in nearly all the streams of Seward Peninsula and miners in the west end of the peninsula have been finding stream tin in greater or less quantities in the concentrates. In July, 1903, a party of prospectors discovered and located a tin-bearing ledge on Lost River, 20 miles west of Teller, which promises to carry good value.

16. BELL, R. N. **Tin in Alaska.**

Mines and Min., Vol. 24, 1904, Scranton, p. 328.

Reprint: Austr. Mg. Stand., Vol. 31, 1904, Sydney and Melbourne, p. 424.

An account of the tin deposits on Cassiterite Creek, a branch of Lost River, Seward Peninsula.

17. BROOKS, A. H. **A new occurrence of cassiterite in Alaska.**

Science, Vol. 13, 1901, p. 593.

Also published in U. S. Geol. Surv. Min. Res. U. S. for 1900 (1901), Washington, pp. 267-271.

U. S. Geol. Surv. Bull., 213, 1903, Washington, D. C., pp. 92-93.

Reconnaissances in the Cape Nome and Norton Bay regions, Alaska, in 1900. Special publication U. S. Geol. Surv., 1901, Washington, D. C., pp. 136-137.

Extract: Mg. Sci. Press, Vol. 82, 1901, San Francisco, p. 203.

Extract: Mg. Journ. Railw. Comm. Gaz., Vol. 72, 1902, London, p. 1375.

Announces the discovery of stream tin in considerable quantities on Buhner Creek, which enters the Anikovik River from the west about three miles from Bering Sea. A sample of concentrates in one of sluice boxes was examined and yielded the following minerals: cassiterite, magnetite, ilmenite, limonite, pyrite, flourite, garnets and gold. Determination of percentage by weight: tinstone 90 per cent, magnetite 5 per cent, other minerals 5 per cent.

18. ———. **Alaska.**

Eng. Mg. Journ., Vol. 79, 1905, New York, pp. 16-18.

An article in which the mineral wealth of Alaska is discussed. Tin is mentioned as having been found in the York region, on Lost River, Cape Mountain, and Ears Mountain, "all of which shows that there is a legitimate field for the tin prospector."

19. COLLIER, ARTHUR J. **A reconnaissance of the northwestern portion of Seward Peninsula, Alaska.**

U. S. Geol. Surv. Prof. Pap. 2, 1902, Washington, D. C., pp. 49-51.

Short description of stream tin and the topography of the country, with theories as to the origin of the stream tin.

ALASKA (Continued)

20. ———. Tin in the York region, Alaska.

Eng. Mg. Journ., Vol. 76, 1903, New York, pp. 999-1000, pl. 1, map.

Gives results of a trip made to investigate the mineral resources of this region. One tin ledge was found, also other minerals of value.

21. ———. Tin deposits of the York region, Alaska.

U. S. Geol. Surv. Bull., 225, 1904, Washington, D. C., pp. 154-167, map 1.

Extract: Mg. Journ. Railw. Comm. Gaz., Vol. 75, 1904, London, p. 505.

Describes the general geology of the York region and the occurrence and character of stream and lode tin deposits.

22. ———. Tin deposits of the York region, Alaska.

U. S. Geol. Surv. Bull. 229, 1904, Washington, D. C., pp. 61, pls. 7, maps 2, figs. 2.

Digest: Mg. Mag., Vol. 10, 1904, New York, pp. 131-132.

Abstract: Mg. Sci. Press, Vol. 89, 1904, San Francisco, pp. 106, 125, 142.

Abstract: Neues Jahrb. Min., 1905, II [Ref.], Stuttgart, pp. 179-181.

Description of placers of Buck Creek and lodes of Lost River and Cape Mountain, Seward Peninsula, Alaska, with references to reported occurrences at other places. Gives a short résumé of the occurrence of tin in other parts of the world.

An elaboration of the article in Bull. 225 (No. 21).

23. ———. Recent development of Alaskan tin deposits.

U. S. Geol. Surv., Bull. 259, 1905, Washington, D. C., pp. 120-127.

Describes the lode and placer deposits of Seward Peninsula, Alaska. Stream tin in the Fairbanks and Dawson regions is mentioned.

24. COURTIS, W. M. Tin in Alaska.

Eng. Mg. Journ., Vol. 73, 1902, New York, p. 143.

A communication describing tin placers 12 miles northeast of York.

25. FAY, ALBERT HILL. Geology and mining of the tin deposits of Cape Prince of Wales, Alaska.

Bi-mo. Bull. Amer. Inst. Mg. Eng., 1907, New York, pp. 769-787, figs. 11, 4 of which are plates.

Abstract: Min. Sci. Press, Vol. 95, 1907, San Francisco, pp. 144-146, figs. 3.

General description of area; climate; vegetation; geology; tin deposits, which he does not consider payable at time of examination; a description of his methods of sampling and fire assaying with KCN. Mining—incomplete account of work done; economic conditions—with table of prices of provisions.

Bibliography of 13 articles on tin at end.

FAWNS, SYDNEY. *See* No. 1320.

26. HESS, FRANK L. The York tin region.

U. S. Geol. Surv. Bull. 284, 1906, Washington, D. C., pp. 145-157, fig. 1.

Editorial on same: Mg. World, Vol. 24, 1906, Chicago, p. 658.

Abstract: Iron Age, May 31, 1906, New York.

Digest: Mines and Min., Vol. 27, 1906, Scranton, p. 158.

Epitome of geology, mineralogy and mining development of the tin deposits of Seward Peninsula, Alaska, to the close of the season of 1905.

27. ———. The York tin region of Alaska.

Eng. Mag., Vol. 32, 1906, New York and London, pp. 352-369, pls. 7, fig. 1.

Practically the same article as "The York tin region" in U. S. Geol. Surv. Bull. 284, 1906, Washington, D. C., pp. 145-157, fig. 1.

28. HILL, J. H. Tin deposits of the York region, Alaska.

Northwest Mg. Journ., Vol. 1, No. 4, 1906, Seattle, pp. 1-2.

General article.

ALASKA (Continued)

28a. ———. York tin mines.

Northwest Mg. Journ., Vol. 7, 1909, Seattle, p. 79.

"A short historical review of the prospecting and development of the placer tin deposits of Seward Peninsula, Alaska."

28b. JACOBS, E. Alaskan Mineral Exhibit at A.-Y.-P. exposition.

Eng. Mg. Journ., Vol. 88, 1909, New York, p. 409.

The exhibit of tin ores, placer and lode, is believed to be the largest purely American production ever made on this continent. Quotes Adolph Knopf as saying that up to close of 1908, the total production of the Seward peninsula tin region was 160 tons of cassiterite concentrates, all of which except a few tons from lode deposits, came from the placers of Buck Creek.

29. KNOPF, ADOLPH. The Seward Peninsula tin deposits.

U. S. Geol. Surv. Bull. 345, 1908, Washington, D. C., pp. 17.

"This paper summarizes the result of the geologic investigations which have been carried on in the Seward Peninsula since the close of 1906. The known Alaskan tin deposits that are of a character sufficiently encouraging to warrant prospecting, are limited to the extreme western part of Seward Peninsula, and are embraced in an area of about 400 square miles."

29a. ———. Geology of the Seward Peninsula tin deposits, Alaska.

U. S. Geol. Surv., Bull. 358, 1908, Washington, D. C., pp. 71, pls. 9. (Including map of western end of Seward Peninsula) and figs. 7.

Describes the geology and mineralogy of the tin deposits of Seward Peninsula, Alaska; mining operations and development; and two new tin-boron minerals, hulsceite and paigeite.

29b. ———. Some features of the Alaskan tin deposits.

Econ. Geol., Vol. 4, 1909, Lancaster, pp. 214-223.

Abstract: Mg. World, Vol. 30, 1909, Chicago, pp. 969-971.

Describes especially the occurrences of tin minerals at Ears Mountain and Lost River, and the occurrence of two new magnesian iron-tin-boron minerals, hulsceite and paigeite at Ears Mountain. Stannite occurs at Lost River in an argentiferous vein. Metasomatic replacement has taken place with little regard to the nature of the country rock.

30. NEWLAND, D. H. Tin.

Min. Ind. for 1902, Vol. 11, 1903, New York and London, p. 587.

Buck and Fillery creeks mentioned as containing alluvial tin. In the latter locality, the wash is about 16 inches in depth, and carries about 8 pounds of 60 per cent cassiterite to the cubic yard.

31. ———. Alaska tin.

Min. Ind. for 1903, Vol. 12, 1904, New York and London, pp. 326-327.

The discovery of lode tin in the Lost River district, about 30 (sic) miles east of Cape Prince of Wales, reported. It occurs in a dike of granite intersecting limestone. The description of tin ore and its occurrence is taken from A. J. Collier's report, U. S. Geol. Surv. Bull. 225, 1904, Washington, D. C., pp. 154-167.

OHLY, J. *See* No. 1215.

32. PAVLOV, A. W. Ueber die primären Zinnlagerstätten in Alaska.

Bull. Mines Indust. or, No. 2, Bd. 2, 1905, Tomsk, map 1.

Written in Russian. This description is based on A. J. Collier's articles.

33. RICKARD, EDGAR. Tin deposits of the York region, Alaska.

Eng. Mg. Journ., Vol. 75, 1903, New York, pp. 30-31.

Describes the geology of the region and occurrence of tin.

ALASKA (Continued)

34. T——. Die Entdeckung von Zinnerzlagern in Alaska.

Berg. Hütt. Zeit., Vol. 60, 1901, Leipzig, p. 434.

Digest: Geol. Centr., Vol. 3, 1903, Leipzig, p. 522.

"Auftreten von Gängen, die Schiefern aufsetzen und enthalten: Magneteisenstein, Titaneisenerz, Brauneisenerz, Schwefelkies, Flusspath, Granat, Gold und vor allem Zinnstein, der dem Gewichte nach 95 per cent der Gangmasse ausmacht. O. v. Linstow."

Evidently taken from Brooks. See reference No. 17.

35. WALCOTT, C. D. Discovery of tin near York, Seward Peninsula.

25th Ann. Rep. Dir. U. S. Geol. Survey., 1903-1904, Washington, D. C., pp. 79.

ARGENTINE REPUBLIC

36. ANONYMOUS. Tin in Argentina.

Écho des Mines, Dec. 30, 1907, St. Etienne.

Translated in Mg. Journ. Railw. Comm. Gaz. Vol. 83, 1908, London, p. 6.

Tin has recently been re-discovered in various parts of Argentina. Deposits were formerly exploited by Jesuits, who obtained tin from the outcrops of the veins for bell metal. Cassiterite occurs in small crystals in granulite near Tinogasta (Catamarca), at the village of Mazan. In La Rioja Province, close to the Catamarca frontier, a company is at work with 100 miners on a stockwerk of small veins occurring in altered granulite dikes. Surface ore gave 7 per cent tin, but in depth the per cent fell to 1 and 1½. Mining is cheap and easy; the country is fairly watered, well wooded and fertile.

37. CASTRO, MARIANO SALAS. Mining in the Province of Salta.

Rep. Secr. of the Immigration Commission, to the Finance Minister of the Province. No. 119. Published in Spanish, English and German, Buenos Aires, [no date], pp. 1-16, map 1.

Tin, gold, silver, coppper and lead deposits reported in departments of Chicoana and La Poma, Province of Salta, Argentine Republic. Bismuth was worked in 1889 in a ravine called Agamillos. Vein said to be six and a half feet wide and forty-four yards deep.

38. HOSKOLD, H. D. Report upon the mines, mining, metallurgy and mining laws, etc., etc., of the Argentine Republic.

Natl. Sect. Mining and Geology, 1904, Buenos Aires, pp. 142-143.

States that cassiterite was found some years since near Tinogasta, Catamarca. After a few tons were mined the vein pinched out. Stream tin had recently been found in a small stream at Mazan, northeast of Chilecito, 6 miles from the frontier line of Catamarca.

ASIA

39. FISCHER, H. Ueber Zinnerze, Aventuringlas und grünen Aventurinquarz aus Asien, sowie über Krokydolithquarz aus Griechenland.

Neues Jahrb. Min., 1882, II, Stuttgart, pp. 90-92.

40. HERMANN, [?]. Native tin.

Journ. prakt. Chem., Vol. 33, Leipzig, p. 300.

Abstract: Amer. Journ. Sci. Arts, ser. 2, Vol. 2, 1846, New Haven, p. 415.

"According to Hermann, native tin occurs in the gold washings of the Ural (Central Asia) in small gray metallic grains containing also some lead."

See also under Burmah, Ceylon, China, East Indies, India, Japan, Laos, Malay Peninsula, Siam, Persia, Philippine Islands.

AUSTRALIA

41. ANONYMOUS. More Australian tin.

Iron, Vol. 5, 1875, London, p. 551. Digest from Geol. Rec., for 1875, London, p. 147.

"Records the discovery of a sample of stream tin ore, weighing about 10 pounds, intermingled with ½ ounce of rough reef gold, at the foot of Mount Pilot, New South Wales. The geological formation consists of superficial deposits of granite."

42. ———. Australian tin at the Philadelphia Exhibition.

Eng. Mg. Journ., Vol. 22, 1876, New York, pp. 72-73, 87.

An account of the development and description of the deposits of the tin producing districts.

43. ———. Tin in Australia.

Min. Ind. for 1899, Vol. 8, 1900, New York and London, pp. 620-621.

Description of alluvial tin deposits on northern coast of New South Wales. Herberton field, Queensland, produced about $1,000,000 worth of stream tin from 1883 to 1894 and nearly $5,000,000 worth of lode tin. Discovery of lode tin reported at Sebastopol, Victoria.

44. ———. The Planet tin mines.

Austr. Mg. Stand. April 5, 1900, Sydney and Melbourne.

Not available to the authors.

45. ———. Tin in Australia.

Min. Ind. for 1901, Vol. 10, 1902, New York and London, pp. 639-641.

New South Wales, Northern territory, Queensland, South Australia, Tasmania and Western Australia tin deposits briefly treated.

46. ———. Australian tin and tin mining.

Mg. Journ. Railw. Comm. Gaz., Vol. 72, 1902, London, p. 225.

Tin deposits are scattered widely over Australia, there being more than 120 known tin localities in New South Wales alone. Tin was discovered in 1851, but not until 1872 were mining operations begun. Native tin has been found in New South Wales. A brief description of occurrences on a number of creeks, and amount of tin mined and exported.

———. *See* also E———, C.

BECK, RICHARD. *See* No. 1299.

47. BENEDICT, WM. DE L. Tin in Australia.

Min. Ind. for 1892, Vol. 1, 1893, New York and London, pp. 442-445.

General survey of the tin deposits of Australia, including New South Wales, Queensland, Victoria, Western Australia and Tasmania.

The tin bearing granite of Australia appears to be closely allied to that of other countries, and has been described as exactly corresponding to that of Cornwall.

48. COGHLAN, T. A. Tin. A statistical account of the seven colonies of Australasia, 1899-1900.

1900, Sydney, pp. 569-572, map 1.

DAUBRÉE, A. *See* No. 1314.

DIEST, P. H. VAN. *See* No. 1478.

AUSTRALIA (Continued)

49. E———, C. The Australian tin mines.

Mg. Journ. Railw. Comm. Gaz., Vol. 44, 1874, London, pp. 396, 507, 643, 751, 833, 973, 1057, 1281, 1394; Vol. 45, 1875, pp. 71, 287.
Mostly statistics of tin production.

50. English, A. G. On Australian and Tasmanian tin.

Mg. Journ. Railw. Comm. Gaz., Vol. 45, 1875, London, p. 19.
Stream tin has been worked in the neighborhood of Ovens, Victoria, for many years in conjunction with gold, also near Albany. Deposits light, would scarcely pay if not accompanied by gold. Stream tin has been found in creeks and rivers in Gippsland. Country is unexplored as yet; cannot predict as to lodes. In the Inverel district of New South Wales, considerable deposits of tin have been worked with varying success. In Queensland, at Stanthorpe, is the largest and most promising deposit of tin. Chief deposit of Tasmania is at Mount Bischoff, 35 miles from Emu Bay, on northwest coast, a mountain 3000 feet above sea level, evidently of volcanic origin, surface stone is composed of decayed granite, porphyry, and quartzose rock, through which tin is disseminated. Wash dirt varies from 3 to 40 feet deep. No overburden beyond a foot or two. Purely lode tin. Probably deposited by some volcanic action. Near the mountain pieces of lode weighing from 1 pound to 1½ cwt. are found; not water worn, and very pure. Assays from 70 to 73 per cent.

Fawns, Sydney. *See* No. 1320.

Fuchs, E., and Launay L. de. *See* No. 1323.

51. Johnson, J. C. F. Getting gold. A practical treatise for prospectors, miners, and students.

1897, Philadelphia and London, pp. 32-33, 600 words.
Short description of the occurrence of tin ore. Confined to Australian examples.

Lock, C. G. Warnford. *See* No. 1338.

Louis, Henry. *See* No. 1340.

52. Mance, F. S. Eastern States of Australia.

Eng. Mg. Journ., Vol. 81, 1906, New York, p. 36.
Reviews tin mining in Queensland, New South Wales and Tasmania, during 1905.

53. Meunier, Stanislas. Sources minérales de l'Australasie (Minerais d'étain de formation actuelle).

Bull. Soc. belge Géol. Pal. Hydr., Vol. 5, 1891, Bruxelles, pp. 8-11.

54. Newland, D. H. Tin in Australia.

Min. Ind. for 1903, Vol. 12, 1904, New York and London, pp. 327-329.
Output and value of tin product during 1903.

55. Newton, E. Wilton. The metalliferous minerals of Australia.

59th Ann. Rep. Roy. Cornwall Polyt. Soc., 1891, Falmouth, pp. 117-131.
Treats of the mineral resources of South Australia, New South Wales, Victoria, Queensland, Western Australia, Tasmania and New Zealand, including tin.

Phillips, J. A., and Louis, H. *See* No. 1350.

56. Plummer, John. Australian tin and tin mining.

Iron Age, Feb. 6, 1902, New York, p. 9, 900 words.
Treats of the location of the deposits, and the extent to which they have been worked.

AUSTRALIA (Continued)

57. REYER, EDUARD. Zinn in Australien und Tasmanien.
Oest. Zeitschr. Berg. Hütt., Vol. 28, 1880, Wien, pp. 47-49, 61-63, 74-76, 85-87.

———. *See* No. 1354.

58. ROBERTSON, J. R. M. The bismuth and tin deposits of Australia.
Trans. Geol. Soc. Glasgow, pt. 1, Vol. 7, 1881-1884, Glasgow, pp. 126-127, 133-142, map.
An account of the origin of the alluvial tin of Australia.

59. STEPHEN, D. Australian and Tasmanian tin ore.
Mg. Journ. Railw. Comm. Gaz., Vol. 49, 1879, London, p. 191.
Gives tin statistics for years 1877 and 1878, showing a decrease of production.

THIBAULT, P. J. *See* No. 1578.

60. TREGAY, W. Australian and Tasmanian tin.
Mg. Journ. Railw. Comm. Gaz., Vol. 48, 1878, London, p. 212.

61. VALE, STEPHEN S. Australian tin deposits.
Trans. Mg. Ass. Inst. Cornwall, Vol. 1, 1887, Camborne, pp. 30-44, map.
General description.

WEEKS, JOSEPH D. *See* No. 1372.

62. WOLFF, G. Australisches Zinn.
Berg. Hütt. Zeit., Vol. 34, 1875, Leipzig, pp. 2-3, 12-14, 24-26, 29-30.
Mit einer Plan-Skizze auf Taf. 1.
Abstract: Oest. Zeitschr. Berg. Hütt., Vol. 23, 1875, Wien, pp. 287-288.

63. WOODS, J. E. T. Tin in Australia.
Mg. Journ. Railw. Comm. Gaz., Vol. 49, 1879, London, p. 225.
Extracts from two letters in which author states that he thinks Australian tin, aside from Mount Bischoff, is of little value.

See under New South Wales, Northern Territory, Queensland, South Australia, Tasmania, Victoria, Western Australia.

AUSTRIA

64. ANONYMOUS. Tin in Bohemia.
Mg. World, Vol. 26, 1907, Chicago, p. 509.
A brief notice of the re-opening of an old tin mine in Bohemia, about 15 miles from Carlsbad. The lodes contain wolframite as well as tin. The new operators are erecting a 100-ton mill, which will be equipped with a magnetic separator and other appliances for recovering both the tin and wolframite.

CHARLETON, ARTHUR G. *See* No. 1310.

65. COTTA, B. VON. Ueber die Zinnerzlagerstätten von Graupen in Böhmen.
Berg. Hütt. Zeit., Vol. 23, 1864, Leipzig, pp. 117-118.

DAUBRÉE, A. *See* No. 1314.

66. FUCHS, E., and LAUNAY, L. DE. Traité des gîtes minéraux et métallifères.
Vol. 2, 1893, Paris, pp. 127-136.
Treats of tin in Saxony and Bohemia.

AUSTRIA (Continued)

GRODDECK, ALBERT. *See* No. 549.

67. HALLWICH, H. Geschichte der Bergstadt Graupen in Böhmen.
1868, Prag.
Schiller, Ph., and Lewald, P. The occurrence of tin ore at Graupen and Upper Graupen, and the manner of mining in ancient and modern times.

JARS, G. *See* No. 416.

68. JOKÉLY, JOH. Das Erzgebirge im Leitmeritzer Kreise in Böhmen.
Jahrb. k. k. geol. Reichs., Vol. 9, 1858, Wien, pp. 549-574, geol. map 1.
1. Zinnerze. 2. Zinnerz gänge im grauen Gneiss. 3. Zinnerz gänge im Felsitporphyr. 4. Zinnerz im Greisen.

69. LAUBE, GUSTAV C. Mittheilungen über die Erzlagerstätten von Graupen in Böhmen.
Jahrb. k. k. geol. Reichs., Vol. 14, 1864, Wien, pp. 159-178, fig. 1.

LEWALD, P. *See* reference No. 67.

70. NEWLAND, D. H. Tin in Austria.
Min. Ind. for 1903, Vol. 12, 1904, New York and London, p. 329.
Tin production for 1903 was 34 metric tons valued at $21,918.

71. NOWICKI, CONSTANTIN VON. Das Vorkommen des Zinnsteins bei Schlaggenwald und Schönefeld.
"Lotos," Zeitschr. Nat., Vol. 7, 1857, Prag, pp. 106-112.

PHILLIPS, J. A., and LOUIS, H. *See* No. 1350.

SCHILLER, PH. *See* No. 67.

SCHULTZ, —. *See* No. 573.

72. VOGELSANG, —. Berg- und hüttenmännische Mitteilungen über Böhmen.
Zeitschr. Berg. Hütt. Sal. preuss. Sta., Vol. 10, 1862, Berlin, pp. B-164-165.
Describes the mining and smelting of tin in Schlaggenwald Bohemia.

See also Bohemia, Saxony, etc.

BANKA

73. AKKERINGA, J. E. Rapport van het distrikt Blinjoe, eiland Bangka.
Jaarb. Mijnw. Ned. Oost-Indië, 1863 (1872), I, Amsterdam, pp. 41-148, I kaart en vijf bijlagen.

———. *See* No. 110.

74. ANONYMOUS. The tin mines of Banca.
Mg. Journ. Railw. Comm. Gaz., Vol. 19, 1849, London, p. 178.
Amer. Journ. Sci. Arts, ser. 2, Vol. 8, 1849, New Haven, pp. 291-292.
Brief history of early tin mining in Banca, and mining methods used at time of writing.

75. ———. Exploitation du minerai d'étain a Banca.
Rev. Univ. Mines Mét. Trav. Publ. Sci. Arts Appl. Indust., ser. 1, Vols. 23, 24, 1868, Liége and Paris, pp. 411-412.

BANKA (Continued)

76. ———. The Banca tin mines.

Iron Age, Vol. 35, 1885, New York, p. 31.

Description of deposits and manner of working them by the Chinese.

77. ———. The best deposits of tin.

Mg. Sci. Press, Vol. 66, 1893, San Francisco, p. 52.

The stanniferous deposits of Banca and Billiton are said to be the best tin deposits in the world. An analysis of Banca metal gave:

Tin	99.961 per cent
Iron	00.019 per cent
Lead	00.14 per cent
Copper	00.006 per cent

There are 200 mines worked in Banca by private companies, while ⅛ of that number are exploited by the Dutch Government. Mines of Billiton are in possession of a private concern, which pays a royalty to the government of 3 per cent of annual yield.

78. ———. Wetten, Gouvernements-Besluiten en Bepalingen betreffende het Mijnwezen in Nederlandsch-Indië.

Jaarb. Mijnw. Ned. Oost-Indië, 1894, Tech. and Admin., Amsterdam, pp. 211-229.

Treats of the methods of tin mining in Banka.

79. ———. Tin in Banka.

Min. Ind. for 1897, Vol. 6, 1898, New York and London, p. 640.

Verbeek (Zeitschr. prakt. Geol., 1897, Berlin, p. 428) is authority for the statement that the duration of the tin deposits of Banka and Billiton is limited. Up to the time of writing, Banka had produced 7,000,000 piculs of tin, and the existing supply amounted to only about 3,000,000.

80. ———. Tin in Banka.

Min. Ind. for 1899, Vol. 8, 1900, New York and London, p. 621.

Mines have been under government control since 1832. Output in 1897 was 9307, raising to 10,220 tons in the succeeding year.

81. ———. Toepassing van graafwerktuigen bij de tinwinning op Banka.

1907, Batavia, pls. 13.

Not available to the authors.

82. Beck, R. Die Zinnerzlagerstätten von Banka und Billiton.

Zeitschr. prakt. Geol., 1898, Berlin, pp. 121-127.

Review of R. Verbeek, Geologische Beschrijving van Bangka en Billiton. Jaarb Mijnw. Ned. Oost-Indië, 1897, Amsterdam.

Beck's article digested: Neues Jahrb. Min., 1899, II, Stuttgart, pp. 266-267.

83. Benedict, Wm. de L. Tin in East Indies.

Min. Ind. for 1892, Vol. 1, 1893, New York and London, pp. 445-446.

Occurrence of tin in island of Banca and Billiton described. Production from islands from 1880 to 1892 given.

84. Boers, R. J. Over het gebruik van krachtinstallaties tot grondverzet bij de tinontginning op het eiland Banka.

(On the application of power machinery for the working of tin ground in the island of Banka.)

Jaarb. Mijnw. Ned. Oost-Indië, Vol. 32, 1903, Batavia, pp. 190-218. With 3 Append., illus. 7, and pls. 5.

85. Bredemeyer, W. Tin mining in Banca.

Mg. Sci. Press, Vol. 25, 1872, San Francisco, p. 21.

Digest: Oest. Zeitschr. Berg. Hütt., Vol. 21, 1873, Wien, p. 76.

BANKA (Continued)

86. CORDES, J. H. Rapport van het distrikt Pangkal-Pinang, eiland Bangka.
Jaarb. Mijnw. Ned. Oost-Indië, 1876 (1878), I, Amsterdam, pp. 89-126. Met eene kaart en twee bijlagen.

87. ———. Rapport over het onderzoek naar het delfstoffelijk productief vermogen van het distrikt Koba eiland Bangka.
Jaarb. Mijnw. Ned. Oost-Indië, 1883 (1885), I, Tech. and Admin., Amsterdam, pp. 67-115. Met eene kaart en twee bijlagen.

88. CRETIER, H. Tinhoudend metaal, tinslak en tinertszand van het zeestrand bij Soengei Liat, district Muntok, residentie Banka.
Jaarb. Mijnw. Ned. Oost-Indië, 1888, Weten. Ged., Amsterdam, pp. 113.

89. CROOCKEWIT, J. H. Scheikundig onderzoek van tinerts, afkomstig v. h. eiland Banka.
1853, Batavia, pp. 14.
Not available to the authors.

———. *See* No. 1473.

90. DIEST, P. H. VAN. Inleiding tot de geognostische mijnbouwkundige rapporten der distrikten van Bangka.
Jaarb. Mijnw. Ned. Oost-Indië, 1872, I, Amsterdam, pp. 3-40.

91. ———. Rapport van het distrikt Soengeileat, eiland Bangka.
Jaarb. Mijnw. Ned. Oost-Indië, 1802 (1872), II, pp. 3-71. 1 kaart en vijf bijlagen.

92. ———. Rapport van het distrikt Merawang, eiland Bangka.
Jaarb. Mijnw. Ned. Oost-Indië, 1864 (1873), I, Amsterdam, pp. 3-75. Met eene kaart.

93. ———. Verslag der onderzoekingen aan den heuvel Sambong Giri, eiland Bangka.
Jaarb. Mijnw. Ned Oost-Indië, 1873, I, Amsterdam, pp. 187-193. Met eene kaart en twee platen.

94. ———. Banca and its streams works.
Translated from Dutch by Foster, C. Le Neve, 1867, Truro.
Not available to the authors.

95. DIJK, P. VAN. Uitkomsten der waarnemingen omtrent eenige onderdeelen der Chineesche ontginningswijze van het tinerts op Bangka, getrokken uit officieele nota's van het jaar 1878 en medegedeeld.
Jaarb. Mijnw. Ned. Oost-Indië, 1879, II, Amsterdam, pp. 55-91.

96. ———. Berekening van de verhounding tusschen de grens van ontginbaarheid der tinertsafzettingen op Bangka en het loon van den Chineeschen mijnwerker (tinprijs, inkoopprijs). Bepaling van beiden, zoodanig dat de te behalen winst op de tinontginning een maximum zij.
Jaarb. Mijnw. Ned. Oost-Indië, 1882, II, Amsterdam, pp. 349-366.

———. *See* No. 1480.

97. DOREN, J. Vrijmoedige beschouwingen tegen het afstaan van de tinmijnen op Banka aan particuliere industrie.
1850, Gravenhage.
Not available to the authors.

BANKA (Continued)

98. EVERWIJN, R. Verslag van een onderzoek naar tinaders in het distrikt Djeboes, eiland Bangka.
Jaarb. Mijnw. Ned. Oost-Indië, 1873, I, Amsterdam, pp. 151-155. Met twee kaartjes.

99. FRAENKEL, S. Bijdrage tot de kennis der tinmijnen van Banka.
1843, Batavia.
Not available to the authors.

FOSTER, C. LE NEVE. *See* No. 94.

FUCHS, E., and LAUNAY, L. DE. *See* No. 1323.

100. GODEFROY, W. Eene verbeterde steekboor (kogelklep-steenboor) voor het onderzoek op tinerts op Bangka.
Jaarb. Mijnw. Ned. Oost-Indië, 1884, II, Tech., Amsterdam, pp. 324-333.

101. GROOT, C. DE. Rapport over de tin-slakken (tra), welke op Bangka onbenuttigd worden weggeworpen.
Jaarb. Mijnw. Ned. Oost-Indië, 1854 (1878), II, Amsterdam, pp. 29-98.

102. HOOZE, J. A. Graphische voorstelling der productie, veilingsprijzen en geldswaarde van Bangka-tin.
Jaarb. Mijnw. Ned. Oost-Indië, 1881 (1882), II, Tech., Amsterdam, pp. 83-87. Met 2 staten en 2 graphische voorstellingen.

103. HORSFIELD, THOMAS. Mineralogical description of the island of Banca.
Journ. Indian Arch. East. Asia, Vol. 3, No. 7, 1848, Singapore, p. 398.
Review: Amer. Journ. Sci. Arts, 2d ser., Vol. 7, 1849, New Haven, pp. 86-101.

104. HUGUENIN, J. A. Rapport van het district Toboali, eiland Bangka.
Jaarb. Mijnw. Ned. Oost-Indië, 1869 (1877), I, Amsterdam, pp. 81-186. Met eene kaart en vier bijlagen.

105. JONGH, D. DE. Over het voorkomen van tinertsaders op het eiland Bangka.
Jaarb. Mijnw. Ned. Oost-Indië, 1883 (1884), II, Tech., Amsterdam, pp. 306-317.
Soengei-Liat. Pangkal-Pinang. Merawang.

106. ———. Over het voorkomen van goud en tinerts op en langs de oostkust van het district Merawang, eiland Bangka.
Jaarb. Mijnw. Ned. Oost-Indië, 1883 (1885), II, Amsterdam, pp. 161-175. Met twee kaarten.
(a) Over het voorkomen van goud op Bangka in het algemeen.
(b) De geologische gesteldheid der kuststreek van Merawang tusschen Tandjong Antoe en de monding der Merawang-rivier.
(c) Het voorkomen van stofgoud en tinerts op de riffen en in de langs het strand gelegene valleitjes.

107. ———. Vervolg op het rapport over het jaar 1883 betreffende het voorkomen van tinader-ertsen op Bangka.
Jaarb. Mijnw. Ned Oost-Indië, 1884 (1885), II, Amsterdam, pp. 176-181.
(a) District Soengei-Liat. (b) District Pangkal-Pinang. (c) District Merawang.

108. ———. Over de uitkomsten der tinwinning op Banka gedurende de ontginnings jaren 1882-83 tot en met 1899-1900 met zes staten en eenige graphische voorstellingen.
Jaarb. Mijnw. Ned. Oost-Indië, 1900, Amsterdam, pp. 51-93.

BANKA (Continued)

109. LANGE. Het eiland Banka en szyne angelegenheder.

Hertzogenbosch. 1850, p. 59 ff.

Describes the tin deposits of Banka.

Not available to the authors.

110. MENTEN, J. H. Het boren en het boormateriaal op Bangka.

Jaarb. Mijnw. Ned. Oost-Indië, 1873 (1874), II, Amsterdam, pp. 163-189. Drie platen:

Hoofdstuk I. Eenige algemeene beschouwingen over het opsporen van stroomtinertsgronden.

II. Beschrijving van het boormateriaal, zooals dit werd ontworpen door wijlen den Mijningenieur J. E. Akkeringa.

III. Wijze waarop het boormateriaal bij de onderzoekingen wordt gebruikt.

IV. Verbeteringen welke het boormateriaal later heeft ondergaan.

MULDER, [?]. *See* No. 1538.

111. OUDEMANS, A. C., JR. Over verontreiniging van Banka-Tin.

Jaarb. Mijnw. Ned. Oost-Indië, I, Tech. en Admin., 1890, Amsterdam, pp. XXIV-XLIV.

112. POSEWITZ, TH. Die Zinninseln im indischen Oceane.

I. Geologie von Bangka. Mitth. Jahrb. kön. ung. geol. Anst., Vol. 7, 1885, Budapest, pp. 153-182.

II. Das Zinnerzvorkommen und die Zinngewinnung in Bangka. Ibid. Vol. 8, 1886, pp. 55-106.

Reviewed by A. Stelzner: Neues Jahrb. Min. 1887, II, Stuttgart, pp. 107-110.

113. RAFFLES, THOS. S. On the tin of the island of Banka.

Trans. Roy. Geol. Soc. Cornwall, Vol. 3, 1827, Penzance, pp. 247-255.

Short history of production of tin in Banka, ruling prices, brief description of placers, distribution of tin in the island and market conditions.

114. RENAUD, G. P. A. Rapport van het district Soengeiselan, eiland Bangka.

Jaarb. Mijnw. Ned. Oost-Indië, 1780 (1874), I, Amsterdam, pp. 3-81.

Met eene kaart en twee bijlagen.

Hoofdstuk I. Vermelding van de wijze waarop de overzichskaart werd vervaardigd.

II. Beschrijving van de natuurlijke gesteldheid van het terrein.

III. Geologische en mineralogische beschrijving.

IV. Beschrijving van de tinertsvoerende valleien en den loop der ontginning.

V. Algemeene blik op het productief vermogen van het district.

115. ———. Overzicht der tinproductie van eenige mijnen in het district Pangkal-Pinang, eiland Bangka.

Jaarb. Mijnw. Ned. Oost-Indië, 1880, II, Amsterdam, 81-82.

115a. ———. Overzicht der tinproductie van eenige mijnen en het district Soengeiselan, eiland Bangka.

Jaarb. Mijnw. Ned. Oost-Indië, 1880, II, Amsterdam, pp. 77-80.

116. ———. Over de Chineesche ontginningswijze van tinerts op het eiland Bangka en de eventueele toepassing daarop van Europeesche werktuigen.

Jaarb. Mijnw. Ned. Oost-Indië, 1882 (1884), I, Tech. en Admin., Amsterdam, pp. 5-121.

Hoofdstuk I. Administratieve regelingen volgens welke de betaling der mijnwerkers geschiedt.

II. De gevolgde methode van ontginning der tingronden en hare onderdeelen.

(a) Grondverzet. (b) Bemaling. (c) Ertswasschen. (d) Smeltkosten. (e) Tin en rijstkruien.

III. Bepaling van het dagloon van den Chineeschen mijnwerker.

BANKA (Continued)

117. REYER, EDUARD. Banka und Bilitong.

Oest. Zeitschr. Berg. Hütt., Vol. 27, 1879, Wien, pp. 384-385, 395-397, 407-409.

Extract: Iron Age, Vol. 24, Nov. 20, 1879, New York, p. 3.

"Concise, though well-detailed notice of the nature and condition of tin-mining in Banka and Billiton, with geological sketch map of the northeast district of the former island, and full references to former observers and writers on these works and the structure of the islands."

———. *See* No. 1354.

SCHUURMAN, J. A. *See* No. 1415.

118. VAN DER WYCK, O. H. The occurrence of tin ore in the islands of Banca and Billiton.

17th Ann. Rep. Dir. U. S. Geol. Surv. 1895-96, pt. 3, 1896, Washington, D. C., pp. 227-242.

Conditions of occurrence, method of mining and smelting tin ore on the islands of Banca and Billiton.

119. VERBEEK, R. D. M. Ueber die Zinnerzlagerstätten von Bangka und Billiton.

Zeitschr. prakt. Geol., 1899, Berlin, pp. 134-136.

Digest: Neues Jahrb. Min., 1901, I (Ref.), Stuttgart, pp. 422-423.

Verbeek's first article on this subject appeared in Jaarb. Mijnw. Ned. Oost-Indië, Vol. 26, 1897, and was reviewed by Beck in Zeitschr. prakt. Geol., 1898, Berlin, pp. 121-127.

———. *See* No. 136.

120. VLAANDEREN, C. L. Scheikundig onderzoek van Bangka-tin.

Jaarb. Mijnw. Ned. Oost-Indië, 1874 (1875), I, Amsterdam, 233-235.

WEEKS, JOSEPH D. *See* No. 1372.

See also Billiton and General.

BILLITON

121. AKKERINGA, J. E. Verslag van een onderzoek naar tinertsaders op het eiland Billiton.

Jaarb. Mijnw. Ned. Oost-Indië, 1873, II, Amsterdam, pp. 3-72. Written in 1860. Met drie kaarten en een plaatje.

Hoofdstuk I. Beschrijving der kaarten.
" II. De ontginbaarheid der tinaders.
" III. Eenige opmerkingen omtrent geognosie, adererts en alluvialen tinerts.

122. ANONYMOUS. Notiz über das Vorkommen von Zinn auf der Insel Billiton [in der Nähe der Insel Banka].

Berg. Hütt. Zeit., Vol. 12, 1853, Leipzig, p. 609.

123. ———. Billiton tin mines.

Eng. Mg. Journ. Vol. 26, 1878, New York, p. 294.

Tin mines in four districts: Mangar (most important), Boeding, Tandjang-Padan, Dindang.

Percentage of pure tin is 40 to 70 per cent. Since 1854 produced 1000 piculs for first year, and for the 20 years after 62,000 piculs.

BILLITON (Continued)

124. ———. Verslag van het Mijnwezen in Nederlandsch Oost-Indië ov het jaar 1880-1.

Jaarb. Mijnw. Ned. Oost-Indië, 1882, II, Tech., Amsterdam, pp. 116-132.
Tinontginningen.
a. Ontginning van Gouvernementswege.
b. Billiton-Maatschappij.

125. ———. Verslag van het Mijnwezen in Nederlandsch Indië over het ja 1881-2.

Jaarb. Mijnw. Ned. Oost-Indië, 1883, II, Tech., Amsterdam, pp. 147-157.
Tinontginningen.
a. Ontginning van Gouvernementswege.
b. Particuliere ontginningen. Billiton.

126. ———. Verslag van het Mijnwezen in Nederlandsch Indië over h jaar 1882-3.

Jaarb. Mijnw. Ned. Oost-Indië, 1884, II, Tech,, Amsterdam, pp. 347-358.
Tinontginningen.
a. Ontginning van Gouvernementswege.
b. Particuliere ontginningen. Billiton.
c. Concessie-aanvragen.

126a. ———. Tin mining in the island of Billiton. A general sketch.

G. Kolff & Co., Batavia (Dutch East Indies), 1908, pp. 31.
Treats of the political, topographic, geological, and commercial aspects Billiton, Dutch East Indies, and its tin mining industry. Describes in excell manner the methods of working the deposits (from the commercial side rather th the mechanical) and handling the Chinese. Besides tin, iron is the only commerc mineral found in quantity. There are small quantities of tungsten, gold, le and copper.
Probably the most intimate English account of tin deposits and mining Billiton Island.

BECK, R. *See* No. 82.

127. CRETIER, H. Tinhoudend zand van Billiton.

Indische Gids, 1881, II.
Not available to the authors.

128. DIEST, P. H. VAN. Bijdrage tot de geschiedenis van Billiton, geduren de eerste 15 jaren onzer vestiging aldaar, bepaaldelijk met het oog het reeds te dien tijde bekend zijn van het voorkomen van tine aldaar.

Jaarb. Mijnw. Ned. Oost-Indië, 1874, II, Amsterdam, pp. 193-240.

129. FERRIER, —. Exploitation de l'étain a Billiton.

Rev. Univ. Mines Mét. Trav. Publ. Sci. Arts Appl. Indust. Ser. 2, Vol. 9, 18 Liége and Paris, pp. 458-460. (Extract.)

FUCHS, E., and LAUNAY L. DE. *See* No. 1323.

130. GROOT, C. DE. Die Insel Billiton durchforscht nach Zinnerz.

Kon. Nat. Tijdschr. Ned.-Indië, Jahr. 3, Lief. 2 u. 3, 1852, Batavia, p. 133, maps
Not available to the authors.

131. ———. Tinader op Billiton.

Kon. Nat. Tijdschr. Ned.-Indië, 1870, Batavia.
Not available to the authors.

BILLITON (Continued)

132. ———. **Herinneringen aan Blitong.**

1887, Gravenhage. Tinerts, pp. 168-228, sketch 1.

Review: Neues Jahrb. Min., 1888, II (Ref.), Stuttgart, pp. 424-425.

1. Tinerts afgezet in het vastgesteente, p. 168.

2. Tinerts dat onvervoerd is blijven liggen op de plaats waar het door verweering van het vastgesteente, waarin het gelegerd was, daaruit werd losgemaakt, p. 189.

3. Laagvorming afgezetten stroomtinertsgrond, p. 199.

4. Stroomtinerts, p. 208.

5. Mineralen, welke met het stroomtinerts in den ertsgrond worden aangetroffen, p. 218.

133. Maier, P. J., and Laudon, J. **Jets omtrent het voorkomen van tin op het eiland Billiton.**

Kon. Nat. Tijdschr. Ned.-Indië, 1854, Batavia.

Not available to the authors.

134. Posewitz, Th. **Die geologisch-montanistischen Verhältnisse der Insel Billiton.**

Petermann's Mitth., Vol. 33, 1887, Gotha, pp. 108-116. Map.

History of the discovery of tin ore in Billiton, geology of the island, the occurrence and mining of tin, statistics of production.

135. Rant, H. F. E. **Verslag van de bevinding en de vooruitzichten der aderontginning nabij den berg Tadjouw op het eiland Billiton.**

Jaarb. Mijnw. Ned. Oost-Indië, 1873, II, Amsterdam, pp. 73-91.

Reyer, Eduard. *See* No. 117.

136. Verbeek, R. D. M. **Geologische beschrijving van Bangka en Billiton.**

Jaarb. Mijnw. Ned. Oost-Indië, 1897, Tech. Admin. en Weten. Ged., Amsterdam, pp. 1-220. Met 4 kaartjes, 2 bijlagen, en 4 platen.

Reviewed by Beck in Zeitschr. prakt. Geol., 1898, Berlin, pp. 121-127.

Beck's article digested: Neues Jahrb. Min., 1899, II [Ref.], Stuttgart, pp. 266-267.

Largely devoted to the manner of occurrence of tin in the islands.

———. *See* No. 119.

Weeks, Joseph D. *See* No. 1372.

See also "General."

BOLIVIA.

137. Anonymous. **Tin mine in South America.**

Mg. Mag. No. 1, Vol. 1, 1853, New York, pp. 210-212.

Extract from "New York Courier" without date. A non-technical and rather careless description of a tin mine at Onero (Oruro ?) probably in Bolivia. Output said to have been 3000 tons per year.

137a. ———. **Zinnvorkommen in Südamerika.**

Oest. Zeitschr. Berg. Hütt. Vol. 8, 1860, Wien, pp. 48-49.

Brief mention of the very rich tin ore to be found in Bolivia, but location is such that the mining of it has not been very practicable.

138. ———. **Tin in Bolivia.**

Min. Ind. for 1895, Vol. 4, 1896, New York and London, p. 571.

Tin production while small, showing a steady increase, and in 1895 production was much larger than ever before.

BOLIVIA (Continued)

139. ———. Bolivian tin and the supply of the United States.

Eng. Mg. Journ., Vol. 66, 1898, New York, p. 632.

Editorial in which is discussed the development of the tin plate industry in United States, and the increasing block tin importation. Why we do not import more raw material from Bolivia is also discussed.

140. ———. L'étain en Bolivie.

Illustration, Vol. 116, 1900, Paris, p. 419.

Review: Berg. Hütt. Zeit., Vol. 60, 1901, Leipzig, p. 268.

141. ———. Tin in Bolivia.

Min. Ind. for 1900, Vol. 9, 1901, New York and London, p. 639.

Tin is mined in the departments of Oruro, Potosi, La Paz and Cochabamba, of which Oruro is much the most important, containing within its borders 25 out of a total of 37 mines of the whole country.

141a. ———. Tin in Bolivia.

Min. Ind. for 1901, Vol. 10, 1902, New York and London, p. 641.

Most important tin mining district is that of Huanuni, where tin ore occurs in numerous veins and lodes, traversing the granite country rock.

142. ———. Tin in Bolivia.

Eng. Mg. Journ., Vol. 73, 1902, New York, p. 218.

Answer to correspondent asking about Bolivia tin deposits. Gives recent production and some other data.

143. ———. Tin in Bolivia.

Mo. Bull. Int. Bur. Amer. Repub., Jan.-June, 1902, Washington, D. C., pp. 588-590.

In the Huanuni district in Bolivia on the mountain of Pozoconi, many of the tin veins run into tin pyrites at from 100 to 200 feet in depth. "Solid tinstone of variable width up to 2 feet." One vein at the Challa and Apacheta mines, 10 miles south of Huanuni is 25 to 30 feet wide, averaging 20 per cent tin. The vein is composed of grains of SnO_2 in an argillaceous rock.

The Arecayo mine of the Oruro district, has lodes from 1 to 3 feet wide and has considerable masses of solid ore, averaging more than 40 per cent tin.

144. ———. A new tin mine, Bolivia.

Mg. Journ., Railw. Comm. Gaz., Vol. 74, 1903, London, p. 525.

Situated 57 miles south of Tupiza, anciently worked in a small way for silver. In 1901 opened as tin mine. Striking in an easterly and westerly direction, lodes cut decomposed clay, slate and shale. Principal lode over 800 feet in length, with an average width of 2 feet. With the rudest dressing machinery, about 23 tons of black tin of 55 per cent to 62 per cent is produced monthly.

145. ———. Tin mining in Bolivia.

Eng. Mg. Journ., Vol. 80, 1905, New York, p. 698.

Brief summary of report of the British Foreign Office. Since rise in price of tin, the famous silver mines of Oruro have depended for their prosperity more on their tin output than silver production. Bolivia now one of the largest producers of tin in the world. Total shipments in 1904 from Oruro district amounted to equivalent of 8000 tons of metallic tin, in 1903 the output was about one-half as large.

146. ———. Tin mining in Bolivia.

Eng. Mg. Journ., Vol. 81, 1906, New York, p. 1137.

Tin deposits of La Blanca, San José and Quinsachata are briefly described, giving output, etc.

BOLIVIA (Continued)

147. ———. Railway and mining development in Bolivia.

Eng. Mg. Journ., Vol. 82, 1906, New York, p. 2, map of S. Bolivia.

"Tin mines of the country are undoubtedly destined to become one of the world's chief sources of supply. Already the Bolivians aspire to the premier place in tin production. The conditions under which this metal is found show wide differences, but it is found throughout a large area, and is undoubtedly abundant."

148. ———. Tin in Bolivia.

Eng. Mg. Journ., Vol. 82, 1906, New York, p. 631.

The prevalent idea that tin ore is superficial in Bolivia, only time will prove or disprove. If there is no notable increase for some time in the output of Bolivian tin, it will not be through want of ore in lodes, but through scarcity of labor.

148a. ———. Producción de estaño en 1906 y 1907.

Geol. Minas, Vol. 2, 1907-1908, Buenos Aires, p. 630.

Gives Bolivian production of tin for years 1906 and 1907.

148b. ———. The mining industries of Bolivia.

Journ. Soc. Arts, Vol. 57, 1909, London, pp. 721-722.

Reprint: Mg. World, Vol. 31, 1909, Chicago, p. 923.

Treats of the Bolivian tin output, market, machinery used, etc.

148c. ———. The tin mines of Huanuni and Uncia, Bolivia.

Mg. Journ. Railw. Comm. Gaz., Vol. 87, 1909, London, p. 125.

Abstract from "El Comercio" (Uʃuni, Bolivia).

Gives brief notes regarding output and improvements in the various mines of Huanuni and Uncia.

148d. ———. Tin Mining in Bolivia.

Eng. Mg. Journ., Vol. 88, 1909, New York, p. 1284.

Extract from undesignated British consular report, giving the total production of barilla during 1908 as follows: Potosi, 18,139 tons; Oruro, 9620 tons; La Paz, 2008 tons; Cochabamba, 170 tons. Total, 29,937.

148e. ———. La producción de estaño en Bolivia.

Cienc. Indust., Vol. 3, 1909, Buenos Aires, p. 209.

148f. ———. Bolivia in 1909.

Mg. Journ. Railw. Comm. Gaz., Vol. 88, 1910, London, p. 136.

Short account of the tin output for 1909, showing an increase over the production of 1908.

149. Arzruni, A. Ueber einige Mineralien aus Bolivia.

Zeitschr. Kryst. Min., Vol. 9, 1884, Leipzig, pp. 73-77.

Review: Neues Jahrb. Min., 1886, I (Ref.), Stuttgart, pp. 198-199.

150. Ballivián, M. V., and Saavedra, Bautista. El estaño en Bolivia. Monografias de la industria minera, No. 3.

Oficina nacional de immigración, estadistica, etc., 1900, La Paz, pp. 133.

151. Barba, Alvaro Alonso. Arte de los Metales.

Madrid, 1630, chap. 32.

Ref. from Frochot, L'étain in Bolivie, Ann. Mines, ser. 9, Vol. 19, 1901, Paris, p. 187.

"C'est encore aujourd'hui une autorite en matiére de mines, et ses indications sur la géographie miniére de la Bolivie ont été très rarement reconnues inexactes."

Not available to the authors.

BOLIVIA (Continued)

A translation was published in London in 1740, entitled: "A collection of scarce and valuable treatises upon metals, mines and minerals. . . . . Being a translation from the learned Albaro Alonso Barba, director of the mines at Potosi in the Spanish West Indies, and the observations of several ingenious persons of our own country, founded on many years experience." Tin, chap. 32, pp. 107-110.

BECK, RICHARD. *See* No. 1299.

152. BENEDICT, WM. DE L. Tin in Bolivia.

Min. Ind. for 1892, Vol. 1, 1893, New York and London, pp. 450-451.

Tin at Potosi is found in large quantities in silver bearing veins. At Chorolque, bismuth and tin are found close together in distinct veins. A few deposits of alluvial or stream tin have been discovered, but only one that is of any importance.

152a. BERKEY, CHARLES P. *See* Rumbold, William R. Origin of Bolivian tin deposits.

Descriptions of microscopic sections of Bolivian tin ores and rocks.

153. BRADLEY, D. H., JR. Mining in Bolivia.

Mg. Mag., Vol. 11, No. 1, 1905, New York, pp. 41-48, 9 illus.

As a tin producing country, Bolivia is second to Malay Peninsula. With the exception of that from Potosi, bar tin, the product of Bolivia is second in quality to none. Deposits rich, output increasing. Tin will undoubtedly be found in many other parts of Bolivia. Bolivian mines offer immense opportunities for investments paying 25 per cent premium within 3 or 4 years.

153a. BROWN, GILMOUR E. Present position of Bolivian tin mines.

Mg. Journ. Railw. Comm. Gaz., Vol. 85, 1909, London, p. 399.

Extract: Mg. World, Vol. 36, 1909, Chicago, p. 829.

A few notes on the cost of mining and smelting, and the names of a few of the principal mines operating in Bolivia.

154. CONWAY, SIR MARTIN. Climbing and exploration in the Bolivian Andes.

New York, 1901, pp. 291-299.

The tin mines of Huaina Potosi are treated from a literary rather than geological standpoint. Veins from 3 meters to 10 meters wide occur in "porphyry," slate and trachyte.

D'ACHIARDI, ANTONIO. *See* No. 1313.

DAVIES, D. C. *See* No. 1317.

155. EMMONS, S. F. Geological distribution of the useful minerals.

Trans. Amer. Inst. Mg. Eng., Vol. 22, 1894, New York, p. 72.

"In Bolivia where tin ore forms an important part of the mineral product, it occurs in andesitic or trachytic rocks of Cretaceous or Tertiary age, is associated with sulphides of silver, copper, lead, zinc and iron and without the usual accompaniment of tourmaline, topaz, fluorspar or apatite."

155a. ENDTER, AUGUSTO. The tin mines of Llallagua, near Oruro, Bolivia.

Mg. Journ. Railw. Comm. Gaz., Vol. 86, 1909, London, pp. 52-53.

Abstracted from "Compañía Estañífera de Llallagua. Tercera Memoria del Directorio y Balance Jeneral al 31 de Diciembre de 1908." Santiago de Chile, 1909, 36 pages with five folding plates.

Treats of the geology, vein structure and mining methods, also announces and describes a newly found pocket of rich ore.

BOLIVIA (Continued)

GMEHLING, ANDREAS. *See* No. 1497.

161. HARRISON, G. Tin in Bolivia.

Diplomatic and Consular reports (Bolivia). Trade of Bolivia for the years 1904-1905, No. 3600, Ann. ser. 1906, London, p. 4.

Mentions tin mining as principal industry.

161a. LIGHT, JOHN. El estaño boliviano y la iniciativa chilena.

Geol. Minas, Vol. 1, 1906-1907, Buenos Aires, pp. 392-397.

Taken from "La Lei," Santiago, Chile.

General article upon tin, particularly of Bolivia.

LOUIS, HENRY. *See* No. 1340.

162. MINCHIN, J. B. Tin mines in Bolivia.

Eng. Mg. Journ., Vol. 51, 1891, New York, pp. 586-587.

Good description of various tin mines of Bolivia, associated ores, manner of working, difficulties of transportation. Most important deposits are situated among the mountain ranges bordering the table-land to the east and northeast of Oruro and Lake Poopo, and are scattered over some 500 square miles. General country rock is shale, more or less highly inclined and contorted from eruptions of trachytic porphyry; the tin veins occur in the latter.

163. MINCHIN, J. B. Mineral resources of Bolivia.

Iron, Vol. 37, No. 962, 1891, London, p. 536.

164. ———. The mineral resources of Bolivia. (Tin mines.)

Engineering, Vol. 51, 1891, London, p. 453.

Tin-bearing country extends along eastern border of Bolivian table-land from lake Titicaca to near the Argentine boundary. At Potosi and Oruro tin is associated with ores of silver, in other places, found alone or mixed with iron oxide and earthy matter. Country rock is shale, inclined and contorted from eruptions of trachytic porphyry; the tin veins occur in the latter rock. Mode of occurrence varies even in one group of mines. Country lacks adequate mining machinery.

165. ———. Tin in Bolivia.

Mo. Bull. Int. Bur. Amer. Repub., No. 55, 1892. Revised to July 1, 1893, Washington, D. C., pp. 74-78.

Short, general, descriptive article, probably taken from his "Tin mines in Bolivia," Eng. Mg. Journ., Vol. 51, 1891, New York, pp. 586-587.

166. ———. Notes on tin mining in Bolivia.

Eng. Mg. Journ., Vol. 75, 1903, New York, p. 31.

Reprint with additions: Mo. Bull. Int. Bur. Amer. Repub., 1904, Washington, D. C., pp. 107-116.

Mines are briefly described. Tin ore occurs chiefly at La Paz on the north, Oruro in the middle, Chorolque on the south and Potosi on the east. Huanuni is richest tin district. Transportation by pack mules, llamas and wagons. The best tin is said to come from Berenguela, 45 miles east of Oruro. Mines were formerly worked for silver. Some of the tin ore is very hard to handle on account of the large amount of antimony and other sulphides. Tin mining develops as transportation becomes easier. 350 tons barilla (concentrates) estimated to give 210 tons of bar tin.

Output of barilla for 1902:			1901:
La Paz	9,536	met. quin.	10,780
Oruro	96,981	" "	100,206
Chorolque	13,365	" "	39,175
Potosi	56,201	" "	68,998
Total	176,083		219,159

BOLIVIA (Continued)

167. ———. Tin in Bolivia.

Min. Ind. for 1902, Vol. 11, 1903, New York and London, pp. 588-590.

General description of tin deposits of Bolivia, methods of working, grade of ore, production, etc.

168. ———. Tin production in Bolivia.

Eng. Mg. Journ., Vol. 77, 1904, New York, p. 244.

Production of tin from mines in the neighborhood of Oruro. Description of the individual mines.

169. ———. Bolivian tin mines.

Mg. Journ. Railw. Comm. Gaz., Vol. 79, 1906, London, p. 361, 450 words.

Reprint: Eng. Mg. Journ., Vol. 81, 1906, New York, p. 810.

A letter dated Oruro, Bolivia, Jan. 26, 1906, giving a short general description of the Bolivian tin mining industry.

170. NEWLAND, D. H. Production of Bolivian mines for 1903.

Min. Ind., Vol. 12, 1904, New York and London, pp. 329-330.

Mines in vicinity of Oruro briefly treated.

171. OCHSENIUS, C. Die Silber-Zinnerz-Lagerstätten Bolivias.

Zeitschr. deutsch. geol. Ges., Vol. 49, 1897, Berlin, pp. 693-695.

171a. OLAECHEA, T. El estaño en Bolivia.

Bol. Min. Indust. Constr., No. 7, ano, 18, 1902, Lima, pp. 51-53 and No. 8, pp. 59-62.

"From an interesting article by Frochot, printed in "Annales des Mines," we extract the points which may be the most directly useful to national [i. e. Peruvian] mining; although the metal referred to has only been known to exist in the department of Puno, it will not be strange if some day, owing to the mineral wealth of the Peruvian soil, tin may be found as a result of new explorations, in conditions where it can be conveniently worked." Then follow extracts from Frochot's article.

172. PASLEY, CHAS. S. The tin mines of Bolivia.

Trans. Inst. Mg. Met., Vol. 7, 1898-1899, London, pp. 77-90, 95.

Digest: Min. Ind. for 1898, Vol. 7, 1899, New York and London, pp. 707-713.

Abstract: Coll. Guard., Vol. 77, 1899, London, p. 18.

Fawns, Sydney.—Tin deposits of the world, pp. 112 et al.

Tin mines in East Cordilleras. Rocks Silurian graywacke, slate, shales, and sandstone, cut by granite and later "porphyritic rocks." Trachyte in south. Formerly worked at Huanuni by Spaniards down to 1000 feet carrying ore out on their backs, two trips a day, 75 pounds per trip. Many rich veins from 1 foot to 30 feet wide and carrying up to 50 per cent tin. Mines located at from 13,000 feet to 15,000 feet altitude. Freights high. Fuel scarce. Tourmaline found with ores. Much antimony, pyrite, bismuth, and arsenic, with some silver, copper, and gold.

PEARCE, R. *See* No. 1630.

172a. PEÑA, ALFONSO DE LA. La explotación de minerales de estaño en Bolivia.

Geol. Minas, Vol. 2, 1907-1908, Buenos Aires, pp. 336-339.

173. PENBERTHY, JOHN. Tin mining in Bolivia.

Eng. Mg. Journ., Vol. 82, 1906, New York, p. 458.

Deposits of Bolivia are both lode and alluvial. Principal centers of production are Chorolque, Potosi, Uncia and Huanuni. The transportation to shipping points

BOLIVIA (Continued)

depends upon rainfall, since absence of grass paralyzes transport which is carried on by mules and llamas. The labor problem is one of great difficulty. With present price of tin, all mines are worked to limit; but it is improbable that there will be an increase in production in the near future owing to the excessive difficulties here encountered.

174. ———. Tin mining in Bolivia.

Amer. Mg. Rev., November 7, 1908, Los Angeles, p. 1, pl. 1. Abstract of paper read beofre Roy. Cornwall Polyt. Soc. of England.

Briefly describes the tin mines and mining conditions existing in Bolivia.

———. *See* No. 467.

PENFIELD, S. L. *See* No. 1631.

PHILLIPS, J. A., and LOUIS H. *See* No. 1350.

175. PREUMONT, G. The Bolivian tin mining industries and railways.

Mg. Journ. Railw. Comm. Gaz., Vol. 83, 1908, London, pp. 5-6, 65-66.

Bolivia presents after the Malayan States the most interesting field for tin mining. Since ore occurs mostly in lodes, it has, in many respects an advantage over those countries depending on alluvial grounds, which are rapidly becoming depleted. Most of the mines are comparatively yet in virgin ground. The possibility of the output increasing rapidly, is largely dependent on better and cheaper methods of transportation. Hence the outlook for railway development is treated at length.

176. ———. Northern tin fields of Bolivia.

Mg. Journ. Railw. Comm. Gaz., Vol. 83, 1908, London, pp. 160, 249, 314.

Gives location, geographic and climatic description of country in which tin deposits occur. The tin-bearing lodes seem to bear no direct relation to the granite core of the mountains, but occur in quartzite on their western flanks. This quartzite is neither very continuous nor very wide, but all areas of it have been found to be stanniferous. The tin fields of Milluni, Quimsa Cruz, Araca and Ichoca occur in such areas. Describes in detail the Huaina-Potosi, Milluni, Araca, Quimsa Cruz, and Santa Vela Cruz fields.

PRIOR, G. T. *See* No. 1636.

Describes teallite.

177. PUNNETT, H. MACAULEY. The tin deposits of Bolivia.

Mg. Journ. Railw. Comm. Gaz., Vol. 33, 1863, London, pp. 403, 443, 479, 498, 554.

Enumeration and description of principal tin districts of Bolivia and modes of working mines, crushing and washing of ores.

ROLKER, CHAS. M. *See* No. 1357.

178. ROBERTS, MALCOLM. Chorolque tin mines and alluvial deposits, Bolivia.

Trans. Inst. Mg. Met., Vol. 9, 1900-1901, London, pp. 372-376.

Geography, geology, mineralogy; description of the mines and their working, also a description of the alluvial deposits.

179. ———. Notes on Chorolque tin mines and alluvial deposits, Bolivia.

Trans. Inst. Mg. Met., Vol. 12, 1902-1903, London, pp. 404-405.

Additions to paper in Trans. Inst. Mg. Met., Vol. 9, 1900-1901, London, pp. 372-376, giving further details of the geology.

180. ROMAÑA, EDUARDO A. L. DE. Una inspeción de los yacimientos de estaño de Bolivia y una exploración por el mismo metal en el Perú.

Boletin Cuerpo de Ingenieros de Minas del Perú No. 57, 1908, Lima, pp. 99, figs. 26, maps 2.

BOLIVIA (Continued)

Abstract: Mg. Journ. Railw. Comm. Gaz., Vol. 84, 1908, London, pp. 37-38, 91-92.

Reviews the uses and production of tin to p. 31; describes Bolivian deposits and their production to p. 68. The remainder of the bulletin describes investigations in the provinces of Huancane and Chucuito, department of Preno. Tin was found at but one place in Peru, on the mountain Calvario in Vilque Chico, where it occurs with lead.

180a. RUMBOLD, WILLIAM R. Origin of the Bolivian tin deposits.

Econ. Geol., Vol. 4, 1909, Lancaster, pp. 321-364, map, figs. 31.

Abstract: Mg. World, Vol. 31, 1909, Chicago, pp. 1063-1066. Map.

The tin ore occurs in Devonian quartzite and quartzite-schist and in quartz porphyry cutting these.

The Concordia lode is in a breccia in a fissure, part of which is occupied by quartz porphyry. Besides cassiterite, the lode carries siderite, tourmaline, sphalerite, and pyrite.

The Elisa and Coya lodes as exposed where worked, are similar to the Concordia.

The Monte Blanco mine, besides having lodes, has schistose quartzite, carrying cassiterite and tourmaline between the laminæ.

The Barrosa Cota Mine works white quartz veins, carrying pyrite, magnetite, and tourmaline, with cassiterite which in some places takes the form of wood tin.

The San Roque and La Boliviania mines work the "Gallofa" lode, which carries iron oxide and pyrite, arsenical pyrite, chlorite, and tourmaline. There is no igneous rock exposed in the mine.

At La Unificada Mine, Negro Pabellon, the lode carries cassiterite with iron oxide, quartz and barite.

Wolframite occurs in veins and pockets of the quartz porphyry.

In the Cataracagua lode at Huanuni, the writer thinks the cassiterite may have been deposited later than iron oxides. Little sulphide has been encountered along the lode.

The Morococala mines are in an inlier of quartzite schist in andesite. A great flow of andesite covers much of the tin-bearing rocks and many of the tin mines are located around the edge of the andesite which, however, has no relation to the origin of the tin ores.

The Antequera, Totoral, and Avicaya mines at Chualla Grande are on impregnation lodes in quartzite and carry cassiterite, quartz, tourmaline, iron pyrite, and less chalcopyrite.

In most of the Llallagua and Uncia veins, there is little impregnation but the walls are slickensided. The average width of the veins is about 2 feet. They carry much iron oxide in the upper portions; below that, sulphides of iron, bismuth, arsenic, antimony, a little silver, and traces of gold. There is no stannite. The writer considers these to be the richest tin mines in Bolivia and probably in the world.

The San José lode is 2 metres wide and carries 20 per cent tin.

The San Salvadora lode is 2 feet wide and is said to carry 25 per cent tin in dense sulphides. It also contains values in bismuth and silver. He claims that with proper handling, the barilla could be made as clean as the tin concentrates from the Malay Peninsula and cleaner than those from Cornwall.

Descriptions of numerous microscopic sections by Charles P. Berkey are quoted.

SPENCER, L. J. *See* No. 1641.

181. STEINMAN, G. Ueber die Zinnerzlagerstätten Bolivias.

Monatsber. deutsch. geol. Ges., No. 1, 1907, Berlin, pp. 7-9.

Translation: Mg. Journ. Railw. Comm. Gaz., Vol. 81, 1907, London, pp. 453-454.

Translation: Informaciones y Memorias, Boletin de la Sociedad de Ingenieros, Vol. 9, 1907, Lima, pp. 133-136.

Gives geological data on the tin deposits of Bolivia, additional to that published by Stelzner.

BOLIVIA (Continued)

182. STELZNER, ALFRED W. Zinnerzlagerstätten von Bolivia.

Zeitschr. deutsch. geol. Ges., Vol. 44, 1892, Berlin, pp. 531-533. Also, Zeitschr. prakt. Geol., 1893, Berlin, pp. 81-82.

Digest: Min. Mag. Journ. Min. Soc., Vol. 10, 1893, London, pp. 261-262.

Digest: Neues Jahrb. Min., 1893, II (Ref.), Stuttgart, p. 81.

"Tin ores in South American Cordilleras are restricted to a zone extending from the 15th to the 21st degree of latitude. In paragenesis and mode of occurrence they offer a remarkable contrast to the tin ores of other countries. The ore is seldom in crystals but usually crypto-crystalline, kidney-shaped, or compact. The usual tourmaline, topaz, fluorite, apatite, etc., are almost entirely absent. Instead of these the tin ore is accompanied by stannite and other sulphides. Frequently the tin is restricted to the upper portion of a vein, its place being taken lower down by argentiferous fahlerz, pyrite, and (locally) galena and zinc blende. In its geological occurrence, the tin ore is remarkable, occurring in association, not with granite, but with trachytes and andesites referred to a late Cretaceous or early Tertiary age."

183. ———. Die Silber-Zinnerzlagerstätten Bolivias.

Zeitschr. deutsch. geol. Ges., Vol. 49, 1897, Berlin, pp. 51-142, map and bibliography.

Ein Beitrag zur Naturgeschichte des Zinnerzes.

Review: Neues Jahrb. Min., 1901, I (Ref.), Stuttgart, pp. 481-483.

———. *See* No. 1642.

184. WENDT, A. F. The Potosí, Bolivia, silver-district.

Trans. Amer. Inst. Mg. Eng., Vol. 19, 1891, New York, pp. 90-91.

"An almost constant accompaniment of the silver ores of Potosí, and of a great many of the silver ores of the plateau of Bolivia, is binoxide of tin, in the shape of gray or yellow oxide. Some of the silver veins are very rich in the oxide of tin, notably so the Tajo-polo and the Veta Estaño, which was named after its contents of tin."

The country rock is rhyolite.

BURMAH

185. ANONYMOUS. Maliwan tin mines [Mergui district].

Ind. Eng. July 20, 1889, Calcutta, pl. 1.

Reprint: Eng. Mg. Journ., Vol. 48, 1889, New York, p. 182.

Digest: Proc. Inst. Civ. Eng., Vol. 98, pt. 4, 1889, London, pp. 468-469.

Description of the almost deserted tin mines of Mergui, near Renaung. Veins of tin-sand are found at the surface, mined in open workings by shallow pits from 10 to 12 feet deep. Sand is raised by ladders from the mines and washed. Two smelting furnaces are situated at Maliwan. Output per day is 15 to 16 blocks of tin of 106 pounds each, bringing about Rs. 60 at Penang.

186. ———. Tin in Burmah.

Min. Ind. for 1900, Vol. 9, 1901, New York and London, p. 639.

187. ———. Tin in Burma.

Mg. World, Vol. 24, 1906, Chicago, p. 96.

Tin occurs in alluvial deposits all along the water courses, covering an area nearly 200 miles in length, by an average breadth of 40 miles. At Maliwan both vein and alluvial tin mining is carried on.

BURMAH (Continued)

188. Foss, K. Mackenzie. The occurrence of tin and gold in Lower Burma.

Mg. Journ. Railw. Comm. Gaz., Vol. 76, 1904, London, pp. 505-506.

Describes an alluvial tin deposit at Henzai. Assayed 73 per cent tin; one particular assay went 48 ounces of gold to ton, and 50 per cent metallic tin. Deposit contains considerable copper and wolframite. Worked by natives in crude manner. Some 28 miles inland from Mergui tin, coal and gold found. Mr. T. W. H. Hughes reported favorably on these deposits.

189. Fryar, Mark. Burma.

Indian Economist, 1872, Calcutta, pp. 445-459.

Not available to the authors.

190. Grundy, James. Mineral production of India.

Trans. Manchester Geol. Soc., Vol. 28, 1902-1904 (1905), Manchester, p. 14.

Tin is mentioned as occurring in Lower Burma. Relatively of small economic importance. Trade is trifling. Practically all the tin mined is used in India.

191. Helfer, J. W. Letter on tin, iron, etc., from Tenasserim.

Journ. Asiat. Soc. Bengal, Vol. 7, 1838, Calcutta, p. 171.

Expresses himself as "greatly satisfied" with tin mines of Tenasserim district. "They are very rich and very extensive."

192. Holland, T. H. Tin ore in Burma.

Rec. Geol. Surv. India, Vol. 31, 1904, Calcutta, p. 43.

Note on discovery of a tin-bearing greisen in Tenasserim.

193. Hughes, T. W. H. Tin-mining in Mergui District.

Rec. Geol. Surv. India, Vol. 22, pt. 3, 1889, Calcutta, pp. 188-208. Sketch map 1. Partly reprinted in Sydney Fawns', "Tin deposits of the world," pp. 39-41.

Has but little hope for lode mining. Stream tin is generally distributed through the gravels. Jungle thick so that exploration is difficult. Mines worked by Chinese, and ore is smelted at the mines. List of mines given.

194. ———. Report on the prospecting operations, Mergui district.

Rec. Geol. Surv. India, Vol. 26, 1891-1892 (1893), Calcutta, pp. 40-53.

Confirms previous reports that tin deposits are large and accessible enough to be worked profitably under economical management. Geology of country gives reason to hope that both north and east of country prospected, other paying tin deposits may be found.

195. King, Will. Tin in Tenasserim.

Rec. Geol. Surv. India, Annual Report for 1888, Vol. 22, pt. 1, 1889, Calcutta, p. 11; for 1889, Vol. 23, pt. 1, 1890, Calcutta, p. 8; for 1890, Vol. 24, pt. 1, 1891, Calcutta, pp. 9-10; for 1891, Vol. 25, pt. 1, 1892, Calcutta, p. 8; for 1892, Vol. 26, pt. 1, 1893, Calcutta, p. 4.

Outlines progress in opening up this new district.

196. Lemon, Chas. and Tremenheere, G. B. Reports on the tin of Province of Mergui, in Tenasserim, in the northern part of the Malayan Peninsula.

Trans. Roy. Geol. Soc. Cornwall, Vol. 6, 1846, Penzance, pp. 68-75.

Description of the occurrences of stream tin in Mergui. States that cassiterite is also found in granite dikes which cut sandstone. Both forms of deposits said to be large, especially those of stream tin.

BURMAH (Continued)

197. LOCK, C. G. WARNFORD. Tin in Burmah.

Economic Mining, 1895, New York, p. 623.

"Burmah is the great source of Indian tin supplies. In the Tenasserim division, tinstone is very plentiful, every stream bed near Maliwun in Mergui yielding the metal when washed. Dr. Oldham states main source of all the Tenasserim tin is the granite range separating province from Siam, where it exists as an essential ingredient of the mass of rock."

198. OLDHAM, T. Remarks on papers and reports relative to the discovery of tin and other ores in the Tenasserim provinces.

Sel. Rec. Bengal Gov., Vol. 6, 1852, Calcutta, pp. 33-44.

Also: Papers on the geology and minerals of British Burmah, 1882, Calcutta, pp. 366-375.

Not available to the authors.

199. ———. Notes on the coal-fields and tinstone deposits of the Tenasserim provinces.

Sel. Rec. Gov. India, Vol. 10, 1856, Calcutta, pp. 31-67.

Also: Papers on the geology and minerals of British Burmah, 1882, Calcutta, pp. 375-406.

Not available to the authors.

REYER, EDUARD. *See* No. 1354.

200. ROYLE, —. On the tin mines of Tenasserim province.

London, Edinburgh, Dublin Philos. Mag. Journ. Sci., ser. 3, Vol. 24, 1844, London, pp. 63-65.

In 1837 tin was discovered near Lake Loadut, about 110 miles north-northeast of Maulmain, and in 1840 the country north of the Pakchan River was reported to be the richest stanniferous district within the Tenasserim provinces. Ore is found in the debris of primitive rocks, and the range is said to be a continuation of the Siamese tin district of Rinowng. In an hour and a half 11,880 grains of tin were collected in the vicinity of the coal mines on Great Tenasserim River.

201. SNOW, A. B. Tin mining in Lower Burma.

Mg. Journ. Railw. Comm. Gaz., Vol. 78, 1905, London, p. 247.

Describes alluvial tin-bearing ground as covering an area nearly 200 miles long with an average breadth of about 40 miles along the water courses. At Maliwûn both lode and alluvial mining is carried on. Veins are from 1 inch to 6 feet wide. Mining is done in most primitive manner by natives. Climatic conditions are favorable.

202. THEOBALD, W. Metalliferous resources of British Burmah.

Rec. Geol. Surv. India, Vol. 6, pt. 4, 1873, Calcutta, pp. 91-93.

"Beyond some workings near Malee-wan on the Pakchan River, the ore is nowhere systematically worked on a large scale within British territory. South of the Pakchan stream the richness of the tin washings is derived from the degradation of a stanniferous granite, in which the tinstone occurs as one of the integral constituents of the rock."

203. TREMENHEERE, G. B. Report on the tin of the Province of Mergui.

Journ. Asiat. Soc. Bengal, Vol. 10, 1841, Calcutta, pp. 845-851. Additions to report, Vol. 11, 1842, Calcutta, pp. 24, 289.

Also, Calcutta Journ. Nat. Hist., Vol. 3, 1843, Calcutta, pp. 47-54.

Sel. Rec. Bengal Gov., Vol. 6, 1852, Calcutta, pp. 5-11; papers on the geology and minerals of British Burmah, 1882, pp. 350-356.

Not available to the authors.

BURMAH (Continued)

204. ———. Second report on the tin of Mergui.

Journ. Asiat. Soc. Bengal, Vol. 11, 1842, Calcutta, pp. 839-851.

Gives more complete description of the tin-bearing ground and of the methods of working, than in earlier report.

205. ———. Report of a visit to the Pakchan River, and some tin localities in the southern portion of the Tenasserim provinces.

Journ. Asiat. Soc. Bengal, Vol. 12, 1843, Calcutta, pp. 528-534, map.

Malewan is only spot in Province where people have located for the purpose of collecting tin. Do not work veins, stream tin alone is collected. Not possible to work except in rainy season, at which time one man can extract four rupees worth of tin per day. Mining done by Chinese. Country rock is granite.

206. ———. Report, etc., with information concerning the price of tin ore of Mergui.

Journ. Asiat. Soc. Bengal, Vol. 14, 1845, Calcutta, pp. 329-332.

207. WARTH, H. Burmah tin deposits.

Eng. Mg. Journ., Vol. 54, 1892, New York, p. 449.

Reprint: Min. Ind. for 1892, Vol. 1, 1893, New York and London, p. 450.

The tin deposits are of two kinds:

1st. Tin gravels found in all or most of the valleys. Gravels are a mixture of quartz, garnet, black tourmaline and gray cassiterite.

2d. Tin-bearing deposits in original eruptive rock, which is weathered so that it is possible to wash out grains of whitish cassiterite which it contains.

The yield from deposits of second class near Malewan was only 0.04 per cent of impure wash tin.

CALIFORNIA

208. ANONYMOUS. Sur les mines d'or, d'argent et d'étain récemment découvertes dan les environs de Los Angeles [Cal.].

Ann. Mines, ser. 6, Vol. 16, 1869, Paris, pp. 599-600.

209. ———. California tin.

Mg. Sci. Press, Vol. 64, 1892, San Francisco, p. 261.

Announcement of the first shipment of pig tin from Temescal, Cal., to New York, which consisted of 22,000 pounds, the output of two weeks. Said to be equal to Straits Settlement tin.

210. ———. The California tin mines.

Eng. Mg. Journ., Vol. 53, 1892, New York, p. 49.

Short account of progress of San Jacinto tin mine during 1891. Outlook bright. Tin raised for 1891 placed at 123,366 pounds having a gross value of $24,673.

211. ———. Tin in California.

Mg. Sci. Press, Vol. 82, 1901, San Francisco, p. 209.

"The metal from Bishop Creek, Inyo Co., Cal., is tin." (Given to show possible tin-bearing locality.)

212. BENEDICT, WILLIAM, DE L. The San Jacinto (Cal.) tin mines.

Eng. Mg. Journ., Vol. 50, 1890, New York, pp. 450-453. Editorial on same, p. 447.

Briefly reviews the unsuccessful attempts made to exploit tin mines in the United States, and the history of the San Jacinto deposits, the metal in which was long thought to be silver. Compares the deposits with those of Cornwall, and gives an epitome of the several reports upon the deposits from which he decides that the deposits should be developed before extensive works are erected.

CALIFORNIA (Continued)

213. ———. Tin in California.
Min. Ind. for 1892, Vol. 1, 1893, New York and London, pp. 452-453
Descriptive, historical, statistical. 269,000 pounds pig tin produced to the time of closing down in September, 1892.

214. BLAKE, WILLIAM P. Occurrence of tin [wood tin] in California, Idaho and Montana.
2d Rep. State Mineralogist, California, 1880-1882 (1882), Sacramento, appendix, pp. 216-218.
California: Tin specimens found in Feather River, Plumas Co.
Montana: Stream tin occurs in many streams of the granitic region of the Bitter Root Mts.; in some localities in sufficient quantities to justify the hope that washing for this ore may be profitable. The many points at which this ore is found in Montana and Idaho indicate that it has a wide and general distribution in the granite region of the Northwest.

215. FAIRBANKS, HAROLD W. Geology of the Temescal tin district.
11th Rep. Cal. State Mg. Bureau, 1893, Sacramento, pp. 111-118.
Describes the geologic features of the region and the system of tin veins.

216. ———. The tin deposits at Temescal, Southern California.
Amer. Journ. Sci., ser. 4, Vol. 4, 1897, New Haven, pp. 39-42.
Also, Mg. Sci. Press, Vol. 75, 1897, San Francisco, p. 362.
Digests: Neues Jahrb. Min., 1899, I (Ref.), Stuttgart, pp. 23-24, 86-87.
Geological description of the district, and of the occurrence of tin.

217. GARRISON, F. LYNWOOD. Tin in the United States.
Eng. Mg. Journ., Vol. 78, 1904, New York, p. 830.
The Temescal tin mine is described.

218. HANKS, H. G. Cassiterite.
4th Rep. California State Mg. Bureau, 1884, Sacramento, pp. 115-123.
Gives a short general dissertation upon the occurrence of tin; describes its ores; gives a list of the alloys of tin and their uses; enumerates the principal localities where tin is found; and describes the Temescal mines.

219. JACKSON [J. R. (?)]. Sur la découverte de minerais d'étain en Californie. (Extraits d'une lettre.)
C. R. Acad. Sci., Vol. 50, 1860, Paris, pp. 105-106.

220. KNIGHT, ENOCH. Temescal tin mines.
Eng. Mg. Journ., Vol. 53, 1892, New York, p. 276, pl. 3.
At writing (end of year 1891), Temescal tin mines (San Jacinto) have produced the first and only American tin ever sent to the market.
Description and reports of mine given.

OHLY, J. *See* No. 1215.

221. ROESSLER, —. New California tin mine.
Eng. Mg. Journ., Vol. 8, 1869, New York, p. 371.
Editorial on same, p. 377.
Announces the discovery of tin near San Jacinto, California. Brief review of California tin mining.

222. WEST, H. E. Tin in California.
Eng. Mg. Journ., Vol. 79, 1905, New York, pp. 852-853.
History, occurrence, and milling and metallurgy of the Temescal mines.

[illegible] (Continued)

[illegible]

[illegible]

[illegible]

[illegible]

CANADA

[illegible]

[illegible]

[illegible]

[illegible]

CANADA (Continued)

Tin has been shown to occur to the extent of 0.17 per cent in zinc ore from the Payne mill, near Sandon, Slocan district, B. C., and traces of tin are reported in lead at the Trail smelter, the ore of which is supposed to have come from the Slocan district.

0. OSANN, A. Oxide of tin.

Ann. Rep. Geol. Surv. Canada, n. s., Vol. 12, 1899 (1902), Ottawa, pp. 72o-73o.

A very small quantity of cassiterite was found in graphitic gneiss derived from limestone, at Graphite City in the Ottawa Valley, Canada.

Proved by this test: "It was dissolved in a borax bead colored slightly blue by copper monoxide; the bead assumed a ruby color or became opaque, resembling red sealing wax." Occurs with rutile, augite, quartz, titanite, pyrite.

1. WOLF, A. G. The Betts process at Trail, British Columbia.

A thesis submitted to the Colorado State School of Mines for the degree of E. M. Read before West. Assn. Tech. Chem. and Met., April, 1907.

Mines and Min., Aug., 1907, Scranton, pp. 11-15.

Mg. World, August 31, 1907, Chicago, pp. 355-356; September 14, 1907, Chicago, pp. 438-439.

States that the refined lead made contains .301 per cent of tin, with small quantities of Ag, As, Sb and Fe.

2. YOUNG, G. A. The tin-bearing locality at New Ross, N. S.

Summ. Rep. Geol. Surv. Dept. of Canada for 1907 (1908), Ottawa, p. 77.

Gives geologic description of the tin bearing area near New Ross.

CAPE COLONY

3. ANONYMOUS. The Kuils River tin field.

Mg. World, Vol. 25, 1906, Chicago, p. 213.

Large extent of alluvial ground; estimated that there is in sight ten million dollars worth of ore. Even the overburden is highly payable. Abundance of water. Country rock mainly granite mostly of fine structure, in places passing into syenite, belonging to the Cape system. Hills are traversed in a north and south direction by bands of greisen, with closely associated quartz lodes dipping to the east.

3a. ———. Kuils River tin mines.

Mg. Journ. Railw. Comm. Gaz., Vol. 82, 1907, London, p. 212.

Taken from "The Cape Argus," July 22, 1907. A newspaper description of the tin placers on the Kuils River, 13 miles from Cape Town.

States that much of the cassiterite is in very fine particles and that the tailings are being worked.

3b. ———. The tin deposits of Cape Peninsula.

South African Mg. Rev., December, 1908, Johannesburg, pp. 2.

Not available to the authors.

3c. ———. Tin mining in the Cape Peninsula.

South African Mg. Journ., Vol. 7, pt. 2, 1909, Johannesburg, p. 221.

Treats of new developments and promising outlook, with comments on Kuils River deposits.

———. *See* No. 1047.

. GRIFFITHS, HARRY D. Notes on tin mining in Cape Colony.

Journ. Chem. Met. Min. Soc. South Africa, Vol. 8, 1907-1908, Johannesburg, pp. 167-181, figs. 6, illus. 2.

CAPE COLONY (Continued)

Abstract: Mg. Journ. Railw. Comm. Gaz., Vol. 62, 1906, London, pp. 119-120.

Describes Knils River tin deposits which are located some 27½ miles southeast of Capetown in hills composed of gray granite, coarsely porphyritic in structure with large quantity of biotite. Ore occurs both as lode and alluvial. Methods and cost of working given.

234a. ———. New methods of concentrating alluvial tin.

Mg. Journ. Railw. Comm. Gaz., Vol. 84, 1908, London, p. 56.

"Describes the new methods introduced at the Knils River tin mines, Cape Colony, which consist in effecting a coarse concentration by means of a rotary pan similar to that used in diamond washing, and then cleaning the rough concentrates in a hydraulic separator to the grade required."

235. Keyzer, S. S. Tin in Cape Colony.

Mg. Journ. Railw. Comm. Gaz., Vol. 82, 1906, London, p. 8.

Description of lode and alluvial deposits occurring in Cape Colony, between Knils River and Stellenbosch.

235a. Wagner, P. A. Notes on the tin deposits in the vicinity of Capetown.

Trans. Geol. Soc. South Africa, Vol. 12, 1909, Johannesburg, pp. 102-111, pl. 1 and figs. 2.

Describes the lode tin deposits at Langverwacht, Hazendal, Welbeloond, Papkuilsfontein, and Hoogekraal and detrital deposits at Langverwacht (Knils River).

The first two occur in quartz veins in white granite dikes cutting granite. The veins carry cassiterite, wolframite, molybdenite, arsenopyrite, pyrite and a little tourmaline. The other three are quartz veins cutting slates, and are accompanied by much more tourmaline, arsenopyrite and pyrite.

At Papkuilsfontein an assay from one vein showed:

Sn = 22.9 per cent.
Bi = 0.27 "
Cu = trace.
As = 22.78 "
Au = 2 dwts. 3 gr. per ton.
Ag = 1 oz. 12 dwts. per ton.

Cassiterite impregnates the country rock, more or less, at all the places.

Fluorite and topaz are absent and no other fluorine-bearing minerals are noted.

NORTH AND SOUTH CAROLINA

236. Anonymous. Tin in North and South Carolina.

Mg. Sci. Press, Vol. 86, 1903, San Francisco, p. 300.

New tin veins have been discovered which give more promise than those formerly known. Manner of occurrence described. Ore strongly resembles the greisen of some of the Black Hills tin mines, although usually more decomposed.

237. ———. Tin ore in North Carolina.

Mg. World, Vol. 21, 1904, Chicago, pp. 174-175, photos 3, sketches 2.

Treated under the heads: geology of the deposits; development work; description of veins; equipment; history of development.

238. ———. Tin in South Carolina.

Mg. Rep., Vol. 50, 1904, Denver, pp. 65-66.

Notice of the discovery of tin in South Carolina on the Ross place.

239. ———. Tin in the Carolinas.

Eng. Mg. Journ., Vol. 82, 1906, New York, p. 823.

"Tin is present in exceedingly irregular pegmatite dikes, as cassiterite, which occurs only as an original constituent of the pegmatite. This mineral is not evenly distributed through the dikes, but is generally segregated or concentrated along certain lines."

Unimportant.

NORTH AND SOUTH CAROLINA (Continued)

239a. BALL, S. MAYS. Tin deposits of the Carolinas.

Eng. Mg. Journ., Vol. 87, 1909, New York, pp. 1139-1140.

Gives brief history of the tin discovery, descriptions of the Ross Mine and other deposits and account of the tin produced in the Carolinas.

240. BENEDICT, WM. DE L. Tin in North Carolina.

Min. Ind. for 1892, Vol. 1, 1893, New York and London, p. 455.

King's Mountain tin deposit treated. The climate of district is very favorable to the disintegration of the rocks, as a result the small gullies running down sides of ledge contain much stream tin in places. Doubtful if ore can be mined at a profit.

241. DABNEY, CHAS. W. Note on cassiterite from King's Mountain, North Carolina.

February, 1884, Raleigh, N. C., 2 page pamphlet.

Also, Journ. Elisha Mitchell Sci. Soc., 1884, Raleigh, pp. 79-81; Geol. North Carolina, Vol. 2, 1888, Raleigh, pp. 347-349.

Brief outline of the discovery and author's examination of the tin deposits at King's Mountain. Two assays are given, one showing 74.41 per cent, the other 65.21 per cent tin.

242. FURMAN, JOHN H. The tin deposits of North Carolina.

Trans. New York Acad. Sci., Vol. 8, 1889, New York, pp. 136-145, pls. 2, figs. 5. Discussion, pp. 145-176.

Location and history of the discovery of the deposits are given with a description of the geology of the occurrences.

242a. ———. The King's Mountain tin region.

The King's Mountain Herald. Vol. 3, Aug. 3, 1905. States that cassiterite was discovered at King's Mountain by Robert Claywell in 1883. Describes the geology of the region, the efforts to mine tin, and the reasons for failure.

243. GARRISON, F. LYNWOOD. Tin in the United States.

Eng. Mg. Journ., Vol. 78, 1904, New York, p. 831.

The tin deposits of the Carolinas are treated among other deposits of the United States.

244. GENTH, FREDERICK A. The minerals of North Carolina.

U. S. Geol. Surv. Bull. 74, Washington, D. C., 1891, p. 35.

Cassiterite found in 1882 near King's Mountain. Short description and partial analysis given.

245. GRATON, L. C. The Carolina tin belt.

U. S. Geol. Surv. Bull. 260, 1904, Washington, D. C., 1905, pp. 188-196.

Digest: Mg. Mag., Vol. 11, 1905, New York, p. 477.

Abstract: Iron Age, Vol. 75, II, 1905, New York, p. 1519.

Development has not yet been sufficient to allow much valuable generalization or prediction regarding these deposits. The Carolina tin belt however, appears to offer a promising field for exploration.

"The tin ore occurs in pegmatite dikes which cut across amphibolites and metamorphosed sediments. There are two varieties of pegmatite. One composed almost exclusively of quartz and microcline, appears to carry no tin. The other, which is tin bearing, is characterized by muscovite in various forms, and plagioclase feldspar, when any feldspar is present. Author believes the pegmatites are of igneous origin, and that the cassiterite is a primary constituent. What caused the segregation of tin ore in certain parts of the dike is not known."—H. Ries.

246. ———. Reconnaissance of some gold and tin deposits of the southern Appalachians.

U. S. Geol. Surv. Bull. 293, 1906, Washington, D. C., pp. 31-57.

Extract: Mg. World, Vol. 25, 1906, Chicago, p. 634.

NORTH AND SOUTH CAROLINA (Continued)

History of tin mining in the Carolinas; geology of tin belt; mining developments; economic importance of tin deposits.

Practically the same article as that in Bull. 260.

247. HESS, FRANK L. The Carolina tin deposits.

Eng. Mag., Vol. 32, 1906, New York and London, pp. 16-26, plates 4, map 1.

General geology of the region, with detailed description of the mines and a short discussion of their probable future, which he considers an unsolved question. Believes cassiterite to be an original constituent of the pegmatite dikes in which it occurs.

248. LEDOUX, ALBERT R. Tin in North Carolina.

Eng. Mg. Journ., Vol. 48, 1889, New York, pp. 521-522. About 2100 words.

Describes King's Mountain tin deposits, method of working and probable future.

249. *See* No. 254a.

250. PHILLIPS, W. B. Tin in North Carolina.

Eng. Mg. Journ., Vol. 43, 1887, New York, p. 111.

Short discussion on the probability of finding tin in paying quantities in North Carolina.

251. PRATT, JOSEPH HYDE. Carolina tin belt.

Min. Res. U. S., 1903, U. S. Geol. Surv., 1904, Washington, D. C., pp. 337-344.

Geographic location; geology; mineralogical and chemical character of ore; production of tin from Carolina belt.

An epitome of Pratt and Sterrett's "The tin deposits of the Carolinas." See No. 252.

252. PRATT, JOSEPH HYDE, and STERRETT, DOUGLASS B. The tin deposits of the Carolinas.

North Carolina Geol. Surv. Bull. No. 19, 1904, Raleigh, pp. 64, figs. 8.

Short abstract: Amer. Journ. Sci., ser. 4, Vol. 20, 1905, New Haven, p. 75.

Introduction; geographical location; geology; mineralogical and chemical character of the ore; associated minerals of the cassiterite; percentage of cassiterite in the veins; development work.

Besides a description of the Carolina ores, a brief resume is given of the other deposits of the world.

253. SLOAN, EARL. Mineral Resources of South Carolina.

Rep. Proc. 7th Ann. Session, Amer. Min. Cong., Portland, Oregon, 1904, pp. 134-147.

Brief account of the discovery of the Ross tin mine, near Gaffney, with description of the vein as shown by work to date.

STERRETT, DOUGLASS B. *See* No. 252.

254. ULKE, TITUS. The occurrence of tin ore at King's Mountain, North Carolina, and near Vesuvius, Virginia.

Min. Res. U. S. for 1893, U. S. Geol. Surv., 1894, Washington, D. C., pp. 178-182.

Describes the character of the country rock of the two localities and the manner of occurrence of the tin ore.

254a. VAN NESS, W. W., JR. Tin in North Carolina.

Eng. Mg. Journ., Vol. 44, 1887, New York, p. 344.

Short description of discovery and workings at King's Mountain.

CEYLON

255. COOMARASWAMY, ANANDA K. Minerals containing rare elements, and associated minerals.

Min. Surv., Ceylon Adm. Rep., 1904 (1905), Colombo, p. E. 10.

CEYLON (Continued)

Note stating that cassiterite had been identified in a specimen of "nambu" from Niriella, near Ratnapura.

256. ———. Report on the occurrence of cassiterite (oxide of tin) in Ceylon.

May, 1905, Colombo. 2 page pamphlet. About 450 words.

Digest: Neues Jahrb. Min., 1906, Stuttgart, I (Ref.), p. 166.

Small amount of stream tin found in gem washing at Niriella (Palle Pattuwa, Nawadun Korale, Sabaragamuwa). Of no commercial importance. Ilmenite occurs with it. Gives analysis.

257. COOMARASWAMY, A. K., and PARSONS, JAMES. Cassiterite.

Min. Surv., Ceylon Adm. Rep., 1905 (1906), Colombo, pp. E. 9-10.

Report of investigation of stream tin at Niriella, Induwehena, near Dela, and in Kuruwita. None of the deposits are of economic importance. The cassiterite is supposed to come from the surrounding granite. Zircon, rutile, ilmenite, etc., are found with the cassiterite.

258. DUNSTAN, WYNDHAM R. Report on cassiterite from Ceylon.

1905, Colombo. About 150 words. Published with article on cassiterite by Coomaraswamy, Mineralogical Survey of Ceylon. Pamphlet of 2 pages.

ANALYSIS OF STREAM TIN FROM NIRIELLA.

Stannic oxide	94.00
Ferric oxide	0.86
Manganous oxide	0.03
Lime	0.50
Insoluble residue, chiefly niobic and tantalic oxides	4.64
	99.83

Equivalent to metallic tin 74.09 per cent.

259. PARSONS, JAMES. Additional report on an occurrence of cassiterite in Ceylon.

1905, Colombo. About 375 words published in pamphlet with article by Coomaraswamy.

Small occurrence of cassiterite (stream tin) in gravels at Noragala. Occurs with sapphire, topaz, and large quantities of zircon.

CHILI

FOULLON, H. *See* No. 1322.

259a. GÖTTING, A. Die Erzgänge zu Punitaqui in Chile, mit besonderer Berücksichtigung der Zinnober führenden Lagerstätten.

Zeit. prakt. Geol., 1894, Berlin, pp. 224-230.

Cassiterite occurs in a diabase in which are also deposits of cinnabar, siderite, copper minerals and gold. The tin is apparently not in commercial quantity. Hornblende granite occurs not far away.

260. MÖRICKE, W. Erzgänge zu Punitaqui in Chile.

Zeitschr. prakt. Geol., 1894, Berlin, pp. 282-283.

Discusses the occurrence of tin mentioned by A. Götting. See No. 259a.

CHINA

261. ANONYMOUS. Zinn-Gruben von Johor in China.

Nouv. Ann. Voy. Sci. geogr., 1827, Paris, p. 418.

Extract: Tasch. ges. Min., 1828, Bd. I, Frankfurt-am-Main, p. 47.

Original article not available to the authors.

Describes the alluvial deposit of tin near the town Gongong.

CHINA (Continued)

262. ———. Tin mines in southwestern China.

Eng. Mg. Journ., Vol. 46, 1888, New York, p. 152.

Notes on a trip by Mr. F. S. A. Bourne, British Consular Agent at Chung King, quoted as stating that more than 1000 men are said to be employed in Southern Yunnan, Kuochinchang, in the tin mines of the region.

263. ———. The mineral resources of China.

Mg. Journ. Railw. Comm. Gaz., Vol. 67, 1897, London, p. 915.

Richest tin mines are located in department of Lingngau-fu, southeastern portion of Yunnan, whence the metal comes in shape of small truncated pyramids weighing about 2 catties each.

264. ———. Tin in China.

Min. Ind. for 1898, Vol. 7, 1899, New York and London, p. 711.

According to a report of the French Commercial Mission, the province of Yunnan now exports annually 2500 metric tons of tin. This is obtained from alluvial deposits at Kotchiou, 20 miles from Moung-tse.

265. ———. Tin mining in Indo-China.

Eng. Mg. Journ., Vol. 80, 1905, New York, p. 829, 200 words.

Tin has been obtained in the province of Yunnan for many years, most of it never reaching the outside world. More recently, alluvial deposits have been opened in the vicinity of Cao-Bang, in the north of Tonkin.

266. ———. Tin production in China.

Eng. Mg. Journ., Vol. 81, 1906, New York, p. 1238.

Note stating that China has long been a producer of tin for domestic consumption, although there is little information on the subject. Amount exported in 1904 was 50,043 piculs, valued at £478,082.

BECK, RICHARD. *See* No. 1299.

BROWNE, FRANK. *See* No. 1458.

266a. COLLINS, W. F. Tin production in Yunnan, China.

Bull. Inst. Mg. Met., Dec. 5, 1909, London, 3500 words, illus. 5.

Abstract: Mg. Journ. Railw. Comm. Gaz., Vol. 88, 1910, London, pp. 195-196, illus.

Review: Eng. Mg. Journ., Vol. 89, 1910, New York, p. 781.

Treats of the occurrence and nature of the mines and ore; mining and concentration; mining laws and customs; dressing and smelting.

D'ACHIARDI, ANTONIO. *See* No. 1313.

267. GROSIER, JEAN BAPTISTE GABRIEL ALEXANDER. A general description of China.

1795, London, p. 400, English Edition.

Mentions that "iron, lead and tin mines must be very common, since these metals are sold at a low rate throughout the whole empire."

268. LECLÈRE, A. Étude géologique et minière des provinces chinoises voisines du Tonkin.

Ann. Mines, ser. 9, Vol. 20, 1901, Paris, pp. 345-348, 439-440, 474-476.

Digest and translation: Trans. Inst. Mg. Eng., Vol. 25, 1902-1903, London and Newcastle-upon-Tyne (1904), p. 823.

Tin occurs at Tomuko, Tsementong, Kotiou, and Malaken, in province of Yunnan. Some of the tinstone occurs in veins in Triassic limestones, but there are also secondary ore bodies, from the decomposition of the limestones and veins. Worked open-cast. "At Malaken the red clay veins worked for tinstone are proving more and more barren of that ore, while the proportion of copper in the infilling increases." The stuff thrown on the wasteheaps is really rich copper oxide.

CHINA (Continued)

269. PANSNER, HOFRATH. Beiträge zu einem Handbuche der Mineralogie des chinesischen Reichs.

Tasch. ges. Min., Vol. 12, II, 1818, Frankfurt-am-Main, pp. 415-416.
Treats briefly of tin and its occurence in China.

269a. WILLIS, BAILEY. Mineral resources of China.

Econ. Geol., Vol. 3, 1908, Lancaster, p. 129.
At present mining and smelting of tin are the most important industrial developments of Yunnan. Metal occurs in veins, no alluvial deposits. Occurs always in red clay, contained sometimes in fissures of limestone, sometimes in the neighboring accumulations of soils. Resources of district in tin cannot easily be estimated. Deposits liable to run out suddenly. Difficult to define probable depth. Production limited by small amount of available water.

COLORADO

270. EMMONS, S. F. Geology and mining industry of Leadville, Colo.

Monogr. U. S. Geol. Surv., Vol. 12, 1886, Washington, D. C., p. 377.
"Tin, indium and cadmium have been detected in furnace products."

271. STEVENS, R. P. On the San Juan Mountains of Colorado.

Trans. New York Acad. Sci., Vol. 5, 1886, New York, p. 128.
States that tin has been found in Colorado. Gives no locality or authority.

CONGO

272. BARRAT, MAURICE. Sur la géologie du Congo Français.

Ann. Mines, ser. 9, Vol. 7, 1895, Paris, p. 459.
"On soupçonne depuis longtemps la presence de l'étain dans le massif cristallin qui apparait sur la côte occidentale d'Afrique, et M. Mizon a récemment attiré l'attention sur l'étain de la Bénoué, qui est l'objet d'un trafic considérable. Dans notre colonie, on n'a encore signalé que des traces de cassitérite dans les monts de Cristal." Whole reference.

273. BUTTGENBACH, H. L'avenir industriel de l'état indépendant du Congo.

Rev. Univ. Mines, Mét. Trav. Publ. Sci. Arts Appl. Indust., ser. 4, Vol. 14, 1906, Liége and Paris, pp. 140-141, map and fig.
Taken from No. 274.

274. ———. L'avenir industriel du Katanga.

1906, Brussels, p. 21, 120 words.
Twenty thousand tonnes of tin said to be in sight in alluvial deposits, a short distance from navigable waters of the Lualaba.

275. ———. La cassitérite du Katanga.

Ann. Soc. géol. Belg., Vol. 33, 1906, Liége, pp. M49-M52, figs. 2.
Digest translation: Trans. Inst. Mg. Eng., Vol. 33, 1908, London and Newcastle-upon-Tyne, pp. 722-723.
Cassiterite occurs in nearly vertical lodes at the junction of a massif of pegmatoid granite with tourmaline quartzites, mica schists, etc. Gold and copper deposits occur not far away. Stanniferous area is rugged and veins sometimes crop out in the ravines, but are usually hidden by debris containing cassiterite pebbles up to several pounds in weight, which are frequently well crystallized.

CONGO (Continued)

276. FARRELL, JOHN R. The copper and tin deposits of Katanga.

Eng. Mg. Journ., Vol. 85, 1908, New York, pp. 747-753, maps 2, illus.

Remarkable deposits in the Congo are being developed, and will be largely productive when railway communication is available. The tin belt extends for a hundred miles in a northeast and southwest direction from the Lualaba to the L rivers just north of a range of granite hills. Cassiterite has been found as allu wash in a number of places. Wash consists of angular fragments of pinkish q mixed with tourmaline, tourmaline schists and schorl rock. Cassiterite cont from 63.5 to 65 per cent tin, unmixed with other metals.

277. FAWNS, SYDNEY. Tin deposits of the world.

London, 1905. Deposits of the Congo Free State, pp. 144-146.

Tin has been found both in alluvial drift and in ledges on the Tanganyika concessions in the Congo Free State about lat. 10° 20′ S., long. 25° 13′ E., and at intervals for 60 miles northwest along the valley of the Lualaba River. Most important discovery at the Busanga Tin Mine, three-quarters of a mile from the junction of the Lufupa and Lualaba rivers. Cassiterite occurs in quartz veins too poor to work. It is also found scattered through the residual alluvium and in the stream gravels.

278. LACROIX, ALFRED. Minéralogie de la France et de ses colonies.

Vol. 3, 1901, Paris, p. 231.

Briefly states that tin has been found in the Congo region.

279. STANIER, X. The geology of the Congo.

Guide de la Section de l'État Indépendant du Congo à l'Exposition Bruxelles-Tervueren, 1897, p. 269.

Trans. Fed. Inst. Mg. Eng., Vol. 15, 1898, Newcastle-upon-Tyne and London, p. 496.

"Commanders Van Gèle and Roget have noticed the existence of stanniferous rocks on the Ubangi and Uelle [Djabbir], and they have also mentioned the presence of objects made from this metal in the hands of the natives. This fact would seem to indicate the presence of workable deposits, and deserves further study, for it is known that tin is a metal very easily extracted, and that its value is sufficiently high for it to support high rates of transport."

EAST INDIES

280. ANONYMOUS. Tin in Singkep.

Min. Ind. for 1897, Vol. 6, 1898, New York and London, p. 641.

A paragraph stating that Singkep tin is to be smelted and sold as Straits tin.

281. BENEDICT, WM. DE L. Tin in Sumatra.

Min. Ind. for 1892, Vol. 1, 1893, New York and London, pp. 449-450.

Tin district described. In comparing the richness of the alluvial deposits of Sumatra with those of Banca it is stated that former yields at the rate of 0.348 lbs. of tin per cubic meter excavated, as against a yield of from 3 to 4½ lbs. in the latter. A number of assays given.

282. CRAWFURD, JOHN. History of the Indian Archipelago, etc.

1820, Edinburgh, Vols. 1 and 3.

Tin: Indigenous to the Archipelago, Vol. 1, p. 182; seldom used by natives in its pure state, Vol. 1, pp. 191-192; where found, Vol. 3, p. 450; history of mining, Vol. 3, p. 452; parallel between the mines of Banca and Cornwall, Vol. 3, p. 464; price and quantity exported, Vol. 3, p. 466; general reflections on the tin trade, Vol. 3, p. 466.

EAST INDIES (Continued)

CRETIER, H. Bijdragen uit het scheikundig laboratorium ven het hoofdbureau van het Mijnwezen in Nederlandsch-Indië te Batavia.

Jaarb. Mijnw. Ned. Oost-Indië, No. 15, 1881, II, Amsterdam, pp. 246-247.
Tinhouded zand van Billiton.

DACH, ROBERT. Ueber das Vorkommen und den Abbau von Zinnseifen auf der Insel Karimon.

Berg. Hütt. Zeit., Vol. 22, 1863, Leipzig, pp. 337-338.
Brief digest: Neues Jahrb. Min., 1864, Stuttgart, p. 365.

DIEST, P. H. VAN. Begrooting van het kapitaal benoodigd voor het in ontginning brengen van tinert bevattende terreinen op het eiland Sinkep, en der voordeelen welke van die ontginning mogen worden verwacht.

Jaarb. Mijnw. Ned. Oost-Indië, 1872, II, Amsterdam, pp. 127-152.

———. Verslag der onderzoekingen aan den heuvel Salinta.

Jaarb. Mijnw. Ned. Oost-Indië, 1873, II, Amsterdam, pp. 145-149. Met eene kaart.

DOORMAN, W. H. C. Die Gewinnung des Zinns in den niederländisch-östindischen Kolonien.

Glück. Berg. hütt. Zeit. Nied. Wesph.; 45 Jahr., 1900, Essen, pp. 844-846.

EVERWYN, R. Forschung nach Zinnerzen in den Landschaften Sukandana, Simpang und Matam [westliche Abtheilung von Borneo] und nach Antimonerzen auf den Karimatainseln.

Kon. Nat. Tijdschr. Ned.-Indië, n. s., Theil 6, 1855, Batavia, S. 58.
Not available to the authors.

———. Forschung nach Zinnerzen in der Landschaft Kandawangan [Südwestspitze von Borneo].

Kon. Nat. Tijdschr. Ned.-Indië, n. s., Theil 9, 1856, Batavia, S. 449.
Not available to the authors.

EVERWIJN, R. Verslag van een onderzoek naar tinerts, op eenige eilanden behoorende tot de residentie Riouw.

Jaarb. Mijnw. Ned. Oost-Indië, 1872, II, Amsterdam, pp. 73-126. Met eene kaart en drie bijlagen.

———. Verslag van eene onderzoekingsreis in het rijk van Siak.

Jaarb. Mijnw. Ned. Oost-Indië, 1874, I, Amsterdam, pp. 83-155.
Chap 2, Geological sketch of country visited; Chap 3, Report on alluvial deposits of Kampar River district. An appendix is added which contains list of the mines worked in Siak.

———. Overzicht van de mijnbouwkundige onderzoekingen, welke tot nu toe door den dienst van het mijnwezen in de wester-afdeeling van Borneo werden verricht.

Jaarb. Mijnw. Ned. Oost-Indië, 1879, I, Amsterdam, pp. 58-82.
Investigation of the tin deposits of Soekadana, Simpang, Matan and Palo.

D'ACHIARDI, ANTONIO. *See* No. 1313.

FAWNS, SYDNEY. *See* No. 1320.

EAST INDIES (Continued)

292. FENNEMA, R. Onderzoek naar tinerts in het gebied der Boven Banjoe-assin, residentie Palembang, naar aanleiding van een valsch bericht van een inlandsch hoofd, uitgevoerd door den opziener der 2e klasse P. J. Tant.

Jaarb. Mijnw. Ned. Oost-Indië, 1878, II, Amsterdam, pp. 233-235.

293. ———. Topographische en geologische beschrijving van het noordelijk gedeelte van het gouvernement Sumatra's Westkust.

Jaarb. Mijnw. Ned. Oost-Indië, 1887, II, Amsterdam, Weten., pp. 248-249.

FUCHS, E., and LAUNAY, L. DE. *See* No. 1323.

294. HAMILTON, ALEXANDER. A new account of the East-Indies.

1727, Edinburgh, Vol. 2, pp. 75, 121.

States that Perak produces more tin than any other district of India. Selangor and Parcelore are also large producers of tin. Gives an account of the discovery of tin in Sumatra.

295. HOCHSTETTER, FERDINAND. Zinn in den niederländisch-östindischen Inseln.

Jahrb. k. k. geol. Reichs., Vol. 9, 1858, Wien, pp. 284-286.

Review: Zeitschr. Berg. Hütt. Sal., preuss. Sta., Vol. 8, 1860, Berlin, pp. XX[illegible] i-XXIII.

296. KOPERBERG, M. Geologische en mijnbouwkundige onderzoekingen in [illegible]de residentie Menado gedurende het jaar 1901 (Celebes).

Jaarb. Mijnw. Ned. Oost-Indië, Vol. 31, 1902, Amsterdam, pp. 147-165. Pl. [illegible] (topogr. maps).

LOCK, C. G. WARNFORD. *See* No. 1338.

297. MENTEN, J. H. Verslag van een onderzoek naar tinerts op het eila[illegible]nd Singkep.

Jaarb. Mijnw. Ned. Oost-Indië, 1876 (1877), II, Amsterdam, pp. 145-177. Met t[illegible] kaarten.

298. NEER, E. A. Verslag omtrent het onderzoek naar tinert-safzettingen in een gedeelte van Midden-Sumatra.

Jaarb. Mijnw. Ned. Oost-Indië, Vol. 31, 1902, Amsterdam, pp. 113-145, pls. 1-3, geol. map.

299. NEWBOLD, T. J. Account of Sungie Ujong, one of the states of the interior of Malacca.

Moor's Indian Archipelago, 1837, pp. 77(a)-84(a).

Brief outline of the tin mining conditions under Dutch occupation. Description of the miners, Malays and Chinese, their methods of mining, smelting, etc. Geological description of tin-bearing country. Quantity produced in Malayan Peninsula and Banca.

300. POSEWITZ, TH. Das Zinnerzvorkommen auf den Inseln des Rio[illegible]uw-Lingga-Archipels.

Petermann's Mitth., Vol. 33, 1887, Gotha, pp. 366-368.

301. ———. Zinnerz auf den Inseln Sumatra, Flores and Borneo.

Ausland, No. 34, 1888, Stuttgart und München, pp. 672-674.

EAST INDIES (Continued)

———. Borneo. Entdeckungsreisen und Untersuchungen. Gegenwärtiger Stand der geologischen Kenntnisse. Verbreitung der nutzbaren Mineralien.

1889, Berlin, pp. 344-345.

Describes the tin deposits of the island of Borneo.

REYER, EDUARD. Zinn in Birma, Siam und Malakka.

Oest. Zeitschr. Berg. Hütt., Vol. 27, 1879, Wien, pp. 563-564, 575-576, sketch map 1.

———. Die Zinnerzlagerstätten von Perak, Malacca, und ihre Ausbeutung.

Berg. Hütt. Zeit., Vol. 47, 1888, Leipzig, pp. 181-183.

———. *See* No. 1354.

ROLKER, CHARLES M. The alluvial tin deposits of Siak, Sumatra.

Trans. Amer. Inst. Mg. Eng., Vol. 20, 1891, New York, pp. 50-84.

Digest: Report on Mineral Industries in the United States at the Eleventh Census, 1890, Washington, D. C., 1892, pp. 257-264.

Reviews briefly the history of tin mining in the East Indies, prefatory to a description of the physical characteristics, rivers, climate, geology, distribution of tin, accompanying minerals, costs of mining, labor supply, tools and customs of the district of Siak, Sumatra. Gives present exports of tin from East Indies.

SCHNEIDER, C. F. A. Geologische Uebersicht über den holländisch-östindischen Archipel.

Jahrb. k. k. geol. Reichs., Vol. 26, 1876, Wien, pp. 122, 134.

TENISON-WOODS, J. E. The geology of Malaysia, Southern China, etc.

Nature, Vol. 33, 1886, London, p. 232.

States that he saw tin ore brought from the Kinebetungen River, Borneo, by D. D. Daly, private secretary of the governor.

WILDMAN, (Consul). Tin in Java.

Eng. Mg. Journ., Vol. 55, 1893, New York, p. 231.

States that a Dutch company has erected works and a smelter at Singkep to test the tin ores discovered at that place. Reports discovery of tin at Jahor.

Original article not available to the authors.

See under Banka, Billiton, New Guinea.

ENGLAND

ABBOTT, GEORGE, JR. An essay on the mines of England; their importance as a source of national wealth and as a channel for the advantageous employment of private capital.

1833, London, pp. 227.

ANONYMOUS. Tin mines. The whole history of the tin works in Cornwall, beginning with their manner of working in the times of the Saxons.

Harleian manuscript, No. 6380. Not available to the authors. Reference made from Boase, G. C., and Courtney, W. P., Bibliotheca Cornubiensis, Vol. 3, 1882, London, p. 1020.

ENGLAND (Continued)

311. ———. Etwas über den Zinn- und Kupferberghau in Kornwallis. Aus Briefen eines reisenden Deutschen vom October, 1783. Aus der handschrift.

Johann Bernoulli's Sammlung Kurzer Reisebeschreibungen, Jahrgang 1784, Vol. [illegible]. Berlin, pp. 363-374.
Not available to the authors.

312. ———. Some observations on the mines of Cornwall and Devon, describing the art of training a load, the art and manner of digging the o[illegible] and the way of dressing and of blowing tin.

Philos. Trans. Roy. Soc. London, abridged, Vol. 1, 1809, London, pp. 56[illegible]
First published in Vol. 6, 1671, pp. 2096-2113.
The working of tin veins ("loads"), and the dressing and smelting of the ore.

313. ———. On the mining district of Redruth.

Quart. Mg. Rev., No. 6, 1832, London, pp. 201-225.
History of the mining and a description of the geology of the district.

314. ———. Tincroft.

Mg. Journ. Railw. Comm. Gaz., Vol. 1, 1835, London, pp. 87, 108.
A history and description of the various lodes and working of the Tincroft mine.

314a. ———. Cornwall and mines.

Dublin University Magazine, Vol. 58 (July), 1861, Dublin, pp. 32-45.
A popular description of tin mining in Cornwall.

315. ANONYMOUS [SALMON, H. C. (?)]. The St. Ives and Levant tin-mini[illegible] district, Cornwall.

Mg. Smelt. Mag., Mo. Rev. Pract. Mg. Quarry. Met., Vol. 3, 1863, London, p. 1[illegible]
Not available to the authors.

316. ANONYMOUS. The system of selling tin ore in Cornwall.

Mg. Smelt. Mag. Mo. Rev. Pract. Mg. Quarry. Met., Vol. 5, 1864, London, [illegible] 6-11, 132-135.

317. ———. Cornish tin-mining. Great Vor district.

Mg. Journ. Railw. Comm. Gaz., Vol. 55, 1885, London, p. 987.
Discusses present mining conditions with special reference to the future of [illegible] Great Vor district.

318. ———. Working low grade tin ores.

Mg. Sci. Press, Vol. 65, 1892, San Francisco, p. 187.
The tin at Wheal Prosper, Cornwall, is doubtless the lowest grade of any in [illegible] world, yet is being worked with profit. Ore runs 3 pounds black tin per ton [illegible] ore, or about 0.13 per cent. Prof. C. Le Neve Foster gives following reasons:
1. Rock soft and friable, easily stamped.
2. Tin in large grains, hence fine stamping is not necessary.
3. The light specific gravity of substances mixed with tin, make separation [illegible] water easy.
4. There is water power at command.

319. ———. Tin mining.

Mg. Sci. Press, Vol. 67, 1893, San Francisco, p. 356.
Some curious statements about tin mining in Cornwall, taken from "Sym[illegible]" Gazetteer" of Cornwall.

ENGLAND (Continued)

——. Cornish tin mining in photograph.

Eng. Mg. Journ., Vol. 58, 1894, New York, pp. 130, 154, 178, 202, 226, 298.

Eighteen excellent photos showing mines, and methods of working, probably taken by J. C. Burrows. See 467.

——. Tin mining in Cornwall.

Mg. Journ. Railw. Comm. Gaz., Vol. 64, 1894, London, p. 928.

Discovery of important tin deposits at the Park of Mines, near St. Columb. Country rock is entirely clay slate. Granite occurs within three-quarters of a mile of mine. Ore occurs in massive and crystallized form, in many small lodes.

——. Tin in England.

Min. Ind. for 1897, Vol. 6, 1898, New York and London, pp. 640-641.

Improvements and economies of Dolcoath mine. The mine shows increased quantity of ore as well as profits.

——. Tin in Great Britain.

Min. Ind. for 1898, Vol. 7, 1899, New York and London, p. 711.

Abstract of report of directors for Dolcoath mine for half year ending June 30, 1898.

——. Tin in Great Britain.

Min. Ind. for 1899, Vol. 8, 1900, New York and London, p. 621.

Treats briefly of Dolcoath mine. Statistics of production given.

——. Cornish tin mining.

Engineer, Vol. 90, 1900, London, p. 172.

Considers reasons why this industry has not revived with the rise in the price of tin.

——. Tin in United Kingdom.

Min. Ind. for 1900, Vol. 9, 1901, New York and London, p. 640.

Report of Dolcoath mine during first half of 1900.

——. Report of Dolcoath mine.

Min. Ind. for 1901, Vol. 10, 1902, New York and London, pp. 642-643.

Statistics of output from 1897 to 1901 given.

——. Tin mining in Cornwall.

Eng. Mg. Journ., Vol. 74, 1902, New York, p. 335.

Rather unpromising outlook. One company paid dividends in 1900 but 1901 used profits in bettering plant. Ore 43.5 pounds of black tin per long ton of ore. Another is losing money with 27 pound ore.

——. The tin mining industry of Cornwall.

Sci. Amer. Suppl., Vol. 63, 1907, New York, pp. 26189-26191, photos 8.

Mining conditions in Cornwall, difficulties to be overcome, and the improvements being made. Writer claims there are yet several million tons of ore awaiting development.

——. Cornish tin mining.

Eng. Mg. Journ., Vol. 86, 1908, New York, p. 181.

A discussion of the costs of tin mining in Cornwall and reasons for loss at some mines.

——. Cornish mining in 1908.

Mg. Journ. Railw. Comm. Gaz., Vol. 85, 1909, London, pp. 12-14.

"A brief account of the commercial conditions, together with tables of output and value of the ore mined in the different districts."

ENGLAND (Continued)

329c. ———. The tin alluvials of Restronguet.
Mg. Journ. Railw. Comm. Gaz., Vol. 85, 1909, London, pp. 175-176.
States, and gives reason for, the belief that tin alluvials of Cornwall are neither exhausted nor too poor to be profitably worked.

329d. ———. British Empire's tin output.
Mg. Journ. Railw. Comm. Gaz., Vol. 85, 1909, London, p. 384.
"Statistics showing output of tin, from 1898-1907 in tonnage and value. These statistics cover the United Kingdom and all the English colonies."

329e. ———. Cornwall and Devon.
Mg. Journ. Railw. Comm. Gaz., Vol. 88, 1910, London, pp. 12-13.
Gives mining conditions especially as to output in the various mines of Cornwall and Devon for year 1909.

329f. ———. Cornish tin alluvials.
Mg. Journ. Railw. Comm. Gaz., Vol. 88, 1910, London, p. 533.
Treats briefly of the possibility of alluvial tin mining in Cornwall.

329g. ———. Camborne, Cornwall.
Mg. Sci. Press, Vol. 100, 1910, San Francisco, pp. 433-434.
Discusses the condition of South Crofty, Carn Brea, Tincroft, Dolcoath, and Wheal Vor mines.

———. *See* No. 1278.

330. ARGALL, WM. On the occurrence of wood-tin ore in the Wheal Metal lode at Wheal Vor in Breage.
Journ. Roy. Inst. Cornwall, Vol. 4, No. 15, 1874, Truro, pp. 255-256.
Description of the wood-tin found and condition under which it occurred.

331. BALDAUF, MARTIN. Bergmännische Reisebriefe aus England.
Oest. Zeitschr. Berg. Hütt., Vol. 56, 1908, Wien, pp. 17-21, figs. 9.
"Describing the geology, and the methods of mining and dressing the ore at the Redruth, Dolcoath and East Pool mines."

331a. BALL, LIONEL C. The Dolcoath.
Queensland Gov. Mg. Journ., Vol. 10, 1909, Brisbane, pp. 58-61, illus.
The first of a series of articles on mining and milling in Cornwall, to allow a comparison of methods used there with those in Queensland.

331b. ———. Some Cornish mines and treatment works.
Queensland Gov. Mg. Journ., Vol. 10, 1909, Brisbane, pp. 108-112, illus.
Describes the mining and milling methods, with short account of the geology of Botallack and Wheal Bassett mines also method of treatment of tin ores at South Crofty and Porth Ledden mills.

331c. ———. Cornish mining.
Queensland Gov. Mg. Journ., Vol. 10, 1909, Brisbane, p. 274, illus. Briefly describes Cornish mining methods.

332. BARNETT, A. K. Observations on the elvan courses, greenstones and sandstones of Cornwall, with remarks on their associated minerals.
Rep. Proc. Min. Ass. Cornwall and Devon, 1873-1874, Falmouth, pp. 69-94, figs. 4.
Some of the elvans or rhyolitic dikes carry tin.

ENGLAND (Continued)

ARROW, GEORGE. The high-level platforms of Bodmin moor, and their relation to the deposits of stream tin and wolfram.

Mg. Journ. Railw. Comm. Gaz., Vol. 83, 1908, London, p. 361. Discussion, p. 384.

Describes three platforms; first, marine, of Pliocene age, at 450 feet above sea, second at 750 feet seen about Camelford, and at foot of Delabole Hill, third at a little less than 1000 feet, first recognized on Davidstow Moor. Superficial deposits which bear tin above 750 feet platform differ very much in places from those below. Here ancient wash is preserved, perhaps protected, from denudation which has destroyed them below this level. The deposits are not so concentrated as the stream-sorted material below. Deposits have been worked in the past, but on account of difficulty of separating wolframite, were abandoned. Since that difficulty has been removed, the industry is reviving, and the wolframite is more valuable than the tin ore.

ARTLETT, THOMAS. A treatise on British mining; with a digest of the cost book system, stannerie and general mining laws.

1850, London, pp. 112.

ATTEN, JOHN, JR. *See* No. 1377.

AWDEN, S. Dislocation of lodes and strata.

Rep. Proc. Min. Ass., Cornwall and Devon, 1866, Falmouth, p. 29.

Not available to the authors.

ECK, RICHARD. *See* No. 1299.

ENEDICT, WM. DE L. Cornwall.

Min. Ind. for 1892, Vol. 1, 1893, New York and London, pp. 439-442.

Early history of tin mining in Cornwall. Statistics of production from 1742 to 1891 given. Geology of Cornwall tin veins described.

ENNETTS, GEO. Tin lodes on Dartmoor.

Mg. Journ. Railw. Comm. Gaz., Vol. 56, 1886, London, p. 963.

ENNETS, SAMUEL. The mining district of St. Agnes.

Trans. Mg. Ass. Inst. Cornwall, Vol. 1, 1887, Camborne, pp. 18-27, discussion, pp. 27-29, pl. 1.

Treats of the peculiarities of tin and other veins of the district, from a geological point of view.

ERGER, J. F. Observations on the physical structure of Devonshire and Cornwall.

Trans. Geol. Soc. London, Vol. 1, 1811, London, pp. 93-184.

Treated under heads:

Tin forming one of the integrant parts of granite; p. 120.

Stream tin, where met with in Cornwall; p. 162.

Course of veins in Cornwall; pp. 163-166.

Estimate of the number of mines of Cornwall, of the different kinds of ore they contain and of their relative ages; pp. 167-175.

Of the different matrices accompanying the mineral deposits in Cornwall and Devonshire; pp. 173-181.

LACK, A. and C. Black's guide to the Duchy of Cornwall, 12th ed.

1883, Edinburgh, pp. 49-54.

A short description of Carclaze tin mine is given on p. 49, and a narrative explanation of tin mining and the handling of tin ores follows.

ENGLAND (Continued)

341. BLAKE, WM. P. The Dolcoath tin mine, Cornwall.
Eng. Mg. Journ., Vol. 54, 1892, New York, p. 414.
Reprint, Sci. Amer. Suppl., Vol. 34, 1892, New York, pp. 14082-14083. Short general article.

342. BOASE, G. C., and COURTNEY, W. P. Bibliotheca Cornubiensis, 3 vols.
1874-1882, London.
Contains a large number of references to Cornwall and Devonshire tin mines, to their geology, customs, laws, history, etc.

343. BOASE, HENRY S. On the tin-ore of Botallack and Levant.
Trans. Roy. Geol. Soc. Cornwall, Vol. 2, 1822, Penzance, pp. 383-403.
Examination of the tin-ore found in some of the St. Just mines; method of dressing it preparatory to smelting; explanation of method of separating the tin and copper from ores of these mines; the result of some experiments on the ore by which it was hoped to find an improved process for separating the copper.

344. ———. Contributions towards a knowledge of the geology of Cornwall.
Trans. Roy. Geol. Soc. Cornwall, Vol. 4, 1838, Penzance, pp. 166-474, pls. 3, 4.
Description of the geology of Cornwall, with "numerous innovations," and deductions with which author has endeavored to disprove some accepted geological doctrines. The tin veins of Cornwall treated.

345. BONNARD, A. H. Note sur le gisement, l'exploitation et le traitement de l'étain dans le Duché de Cornouailles.
Journ. Mines, No. 84, Vol. 14, 1803, Paris, pp. 443-454.
"The author more particularly describes Polgooth mine, Carclaze mine and Pentowan stream work, near St. Austell, from personal observations."

346. BORLASE, WM. COPELAND. Natural history of Cornwall.
1758, Oxford.
Not available to the authors.

———. *See* Nos. 1381, 1382, and 1383.

347. BORLASE, REV. WM. COPELAND, and ROSEWARNE, H. Extract of letters giving an account of a specimen of native tin found in Cornwall.
Philos. Trans. Roy. Soc. London, Vol. 12, 1760, London, p. 507-508.

BROWN, A. SELWYN. *See* No. 1308.

348. BRUNNICH, MORTEN THRANE. Beschreibung zweyer Zinnerze.
Kön. Schwed. Akad. Wiss. Abh. Nat. Haush. Mech., Vol. 40, 1778 (Pub. 1782), Leipzig, pp. 307-310.
Treats of tin ores of Cornwall.

349. BULLER, JOHN. An account of the Parish of St. Just.
1842, Penzance.
Not available to the authors.

BURNARD, ROBERT. *See* No. 1384.

350. BUSZ, K. Mittheilungen über den Granit des Dartmoor Forest in Devonshire, England, und einige seiner Contactgesteine.
Neues Jahrb. Min., Beilage-Band 13, 1899, Stuttgart, pp. 90-139, pl. 1, fig. 1.
Page 100: Hornfels consists of light colored mica, quartz and tourmaline. Innumerable grains of cassiterite occur through it. Isolated by HF and metallic tin obtained. Describes also a garnet-datolite hornfels and a hedenbergite hornfels with accessory garnet, datolite, axinite, and quartz.

ENGLAND (Continued)

CARCANAGUES, —. *See* No. 1651.

351. CAREW, RICHARD. Survey of Cornwall.

1811, London, pp. 25-60.

The first edition of this work was issued in 1602. Description of stream works and lode-mines; names of mines; mode of working; ore dressing; sharing black tin; tin coinage (paying tribute in metal); commercial practices; and courts.

352. CARNE, JOSEPH. An account of the Relistian tin mine.

Philos. Trans. Roy. Soc. London, 1807, London, pp. 293-295.

Journ. Nat. Philos., Chem. Arts, ser. 2, Vol. 20, 1808, London, p. 24.

Short description of pebbles of chlorite schist cemented by crystallized tin, which occurred in this mine.

353. ———. On the relative age of the veins of Cornwall.

Trans. Roy. Geol. Soc. Cornwall, Vol. 2, 1822, Penzance, pp. 49-128, pls. 1, 2.

The tin veins, among other metalliferous veins, are treated with regard to their age in relation to the country rocks.

354. ———. On the mineral productions, and the geology of the parish of St. Just.

Trans. Roy. Geol. Soc. Cornwall, Vol. 2, 1822, Penzance, pp. 290-358. Map of Parish of St. Just.

Treated under heads:

The tin of the parish described, pp. 292-294; description of veins, pp. 321-323; tin floors, pp. 326-331; the stream works of Parish, pp. 331-333; tin mines, pp. 339-344; ancient modes of mining, pp. 345-350; ancient history of the "Cassiterides," pp. 354-358.

355. ———. A description of the stream-work at Drift Moor, near Penzance.

Trans. Roy. Geol. Soc. Cornwall, Vol. 4, 1838, Penzance, pp. 47-56.

Antiquity of diggings and proof of the deluge.

356. ———. An account of the discovery of some varieties of tin-ore in a vein, which have been considered peculiar to streams, with remarks on diluvial tin in general.

Trans. Roy. Geol. Soc. Cornwall, Vol. 4, 1838, Penzance, pp. 95-112.

Describes wood tin, toadseye tin, and sparable-tin found in Garth mine, or East Wheal Cock.

356a. ———. Statistics of the tin mines in Cornwall, and of the consumption of tin in Great Britain.

Journ. Statis. Soc., London, Vol. 2, 1839, London, pp. 260-268.

Gives a brief history of tin smelting, the exports, imports and prices of tin from 1750 to 1837.

357. ———. Pseudomorphous minerals of Cornwall.

Trans. Roy. Geol. Soc. Cornwall, Vol. 6, 1846, Penzance, pp. 29-30.

Crystals of feldspar and quartz wholly or partially replaced by SnO_2.

358. CHAPLIN, G. P. Cornish methods of mine timbering.

Trans. Fed. Inst. Mg. Eng., Vol. 13, 1897, Newcastle-upon-Tyne and London, pp. 200-210, pl. 11.

Some data about timbering. New Dolcoath shaft vertical and 18½ feet in diameter. It is bricked and expects to cut the lode at 2500 feet depth. The rocks of the mine are generally solid and need little timbering, but timbers 2 feet square and 30 feet long are sometimes used.

ENGLAND (Continued)

CHAPMAN, E. J. *See* No. 1597.

359. CODRINGTON, T. On some submerged rock-valleys in South Wales, Devon and Cornwall.

Quart. Journ. Geol. Soc. London, Vol. 54, 1898, London, pp. 269-278.
Treats of the stream tin deposits of Cornwall.

360. COLENSO, JOHN W. A description of Happy-Union tin stream work at Pentuan.

Trans. Roy. Geol. Soc. Cornwall, Vol. 4, 1838, Penzance, pp. 29-29.
Overburden 53 feet. Tin from finest sand to large pieces of 200 pounds. Averages about .9 of 1 per cent of the gravel.

361. COLLINS, J. H. A handbook to the mineralogy of Cornwall and Devon. With instruction for their discrimination, and copious tables of localities.

1871, Truro, pp. 108, pls. 10.

362. ———. Note on a portion of the incrusted surface of a block of "Jews' Tin."

Journ. Roy. Inst. Cornwall, Vol. 4, 1872, Truro, pp. 83-84.
Abstract: Chem. News, Vol. 25, 1872, London, p. 271.
Analysis of the crust which covered a part of a block of "Jews' Tin," and which appeared to be chiefly peroxide of tin, probably formed by the slow oxidation of the outer surface of the block of metallic tin.

363. ———. Note on the rocks and Goonbarrow mines near St. Austell.

Rep. Proc. Min. Ass. Cornwall and Devon, 1872-1873, Truro, pp. 66-69, figs. 2.
Description of the occurrence of tin at Goonbarrow mines.

364. ———. On the mining district of Cornwall and West Devon.

Proc. Inst. Mech. Eng., 1873, Birmingham, pp. 89-106. Discussion pp. 107-118, pls. 22-36.
Treated under the heads:
Mineral lodes; tin and copper mines; quantities and values of the ores.

365. ———. Note on the occurrence of stanniferous deer horns in the tin gravels of Cornwall.

Trans. Roy. Geol. Soc. Cornwall, Vol. 10, 1887, Penzance, pp. 98-100.
Abstract: Amer. Journ. Sci. ser. 3, Vol. 22, 1881, New Haven, pp. 81-82, 175 words.
Description of deer horns which have been partly replaced by percolating stanniferous solutions. In some parts, the original horn structure is almost entirely preserved or reproduced in oxide of tin.
(Note: J. B. Scrivenor in a later examination of similar horns found the tin to be mechanically deposited and not a replacement. See 726b.)

366. ———. On the geology of Cornwall.

Proc. Geol. Ass., Vol. 10, 1889, London, pp. 101-111.
Treated under heads: Mineral lodes, stockworks; tin stream work; lode workings.

367. ———. On the origin and development of ore deposits in the west of England.

Journ. Roy. Inst. Cornwall, Truro.
Chaps. I and II, Vol. 10, 1891, pp. 109-149, figs. 13. Chap. III, Vol. 11, 1893, pp. 111-184, figs. 16. Chap. III, Vol. 11, 1893, pp. 327-377. Chaps. III and IV, Vol. 12, 1896, pp. 49-75. Chap. V, Vol. 13, 1899, pp. 283-312.

ENGLAND (Continued)

Chap. I, Vol. 10, Formation of structural planes in rock masses.
Chap. II, Vol. 10, The mechanical phenomena of faulting.
Chap. III, Vols. 11 and 12, Rock-change as affecting the formation of ore deposits.
Chap. IV, Vol. 12, The formation and natural concentration of detrital deposits.
Chap. V, Vol. 13, The relative ages of the ore deposits of the west of England.
The tin deposits of England are treated in this series of articles, along with other metalliferous veins.

68. ———. Cornish mines and Cornish miners.
65th Ann. Rep. Roy. Cornwall Polyt. Soc., Vol. 65, 1897, Falmouth, pp. 64-96.
Journ. Soc. Arts, Vol. 47, 1899, London, pp. 359-376.
Treated under heads:
Antiquity of mining; the valley gravels; submarine tin gravels; the "Old Men"; copper and other minerals; deep mining; pumping machinery; winding apparatus; ore dressing; boring machines; the great extent of mining operations; tin; the first great collapse; the revival; the culmination; product of some leading mines; the future of Cornish mining.

69. ———. The precious metals in the west of England.
Journ. Roy. Inst. Cornwall, Vol. 16, pt. 1, 1904, Truro, pp. 103-119.
Article treats of the gold and silver of the West of England. Stream tin at Treloy frequently had mixed with it grains of gold, mostly about the size of wheat grains, sometimes as large as peas.

———. *See* Nos. 1385 and 1598 (Cornish tinstones).

70. COMBES, CHAS. Mémoire sur l'exploitation des mines des comtés de Cornwall et de Devon.
Ann. Mines, ser. 3, Vol. 5, 1834, Paris, pp. 109-144.

70a. CONRAN, R. H. Tin mining in Cornwall.
Austr. Mg. Eng. Rev., Vol. 1, 1909, Sydney and Melbourne, pp. 279-282, illus.
Abstract: Mg. World, Vol. 31, 1909, Chicago, pp. 549-551, illus.
Brief history of early mining and geological description of the country with more detailed account of mining methods.

71. COTTA, BERNARD VON. A treatise on ore deposits.
Translated by F. Prime, 1870, New York, pp. 406-427.
Summary of the ore deposits of Cornwall.

72. COUCH, R. Q. Notice of the occurrence of the horns and bones of several species of deer in the tin works of Cornwall.
Trans. Roy. Geol. Soc. Cornwall, Vol. 7, 1865, Penzance, pp. 185-191.
The author, describing a certain specimen, says, "the whole horn had undergone a change into tin ore." But thinks that possibly this may not imply solution of the tinstone.

D'ACHIARDI, ANTONIO. *See* No. 1313.

73. DAHLBLOM, TH. Ueber die Cornwaller Zinngruben.
Jern-Kont. Ann. 1890, Stockholm, p. 334.
Review: Berg. Hütt. Zeit., Vol. 50, 1891, Leipzig, p. 290.

DAUBRÉE, A. *See* No. 1314.

DAVEY, STEPHEN. *See* No. 1603.

ENGLAND (Continued)

374. DAVIES, ALFRED T. The phenomena of heaves or faults in the mineral veins of St. Agnes, Cornwall.

Rep. Proc. Min. Ass. Cornwall and Devon, for 1879 (1880), Truro, pp. 12-33, figs. 21.
Discussion of vein or lode formation, with a number of practical rules and diagrams for the guidance of miners showing how to follow the continuation of veins which have been faulted or heaved. Applies to the tin veins of the district.

DAVIES, D. C. *See* No. 1317.

375. DAVY, SIR HUMPHRY. Hints on the geology of Cornwall.

Trans. Roy. Geol. Soc. Cornwall, Vol. I, 1818, Penzance, pp. 38-50.
Notes on the occurrence of tin in Cornwall.

DECHEN, H. VON. *See* No. 545.

376. DE LA BECHE, HENRY T. Report on the geology of Cornwall, Devon and West Somerset.

Mem. Geol. Surv. Great Britain, 1839, London, pp. 1-648, maps and plates.

376a. DEW, J. H. W. Cornish tin alluvials.

Mg. Journ. Railw. Comm. Gaz. Vol. 88, 1910, London, pp. 599-600.
Correspondence concerning tin bearing gravels in Cornwall.

DIETZSCH, F. *See* No. 1479.

377. DREW, S. History of Cornwall. 1824.

Not available to the authors.

378. DUFRÉNOY, P. A., and BEAUMONT, ELIE DE. Notice sur le gisement, l'exploitation et le traitement des minerais d'étain et de cuivre du Cornouailles.

Ann. Mines, Vol. 9, 1824, Paris, pp. 827-908, Vol. 10, pp. 331-366, 401-426; Vol. 11, pp. 207-254.
Reprint: Arch. Bergb. Hütt. Vol. 13, 1826, Berlin, pp. 60-185.
Reviews: Zeitschr. Min., 1826, II, Frankfurt-am-Main, pp. 427-439.
Ann. Sci. Nat., Vol. 7, 1826, Paris, pp. 195-243.

EDMONDS, RICHARD. *See* No. 1389.

379. ENGLISH, HENRY. A compendium of useful information relating to the companies formed for working British mines, containing copies of the prospectuses, amount of capital, number of shares, names of directors, etc., with general observations on their progress, detailing their operations, mines in their possession and original information.

1826, London, pp. 124.

FAWNS, SYDNEY. *See* No. 1320.

FERGUSON, HENRY T. *See* No. 1654.

379a. FEUVRE, P. A. Cornish Mining.

Times Eng. Suppl., Vol. 1, 1905, London, pp. 250, 273, 274, and 309-310.
Discusses briefly economic conditions of tin mining in Cornwall. Quotes Robert Hunt to the effect that the tin lodes down to 600 feet in depth average 3.97 feet wide, and below that 3.36 feet, and Henry Louis as saying that the average tin content is 2 per cent. In the second article dues and royalties and their effect upon Cornish tin mining are discussed. The third article treats of working costs.

ENGLAND (Continued)

'LETT, J. S. On some brecciated stanniferous veinstones from Cornwall.
Mem. Geol. Surv. Great Britain, for 1902 (1903), London, pp. 154-159.
Microscopic examination of tin-bearing veinstones from following mines: Dolcoath, Wheal Basset, South Crofty, Carn Brea, Wheal Kitty and West Kitty. Essential constituents of these tin ores are quartz, tourmaline, chlorite and cassiterite. Fluorspar, pale micas, iron oxides, copper pyrites, kaolin (?) are present also, but not universally, occasionally there are pieces of altered feldspar and fragments of granite or slate.

'OSTER, C. LE NEVE. Notes on the Rosewarne mine.
Trans. Cornwall and Devon Min. Ass., 1866, Camborne, p. 26.
Not available to the authors.

———. Report on the inspection of metalliferous mines in Cornwall, Devonshire and a part of Somersetshire for the year ended 31st December, 1873.
Rep. Insp. Mines for 1873 (1874), London.
Parl. Pap., Vol. 13, 1874, London, pp. 295-321.
Gives statistics regarding mines of district.

———. The tin deposits of East Wheal Lovell.
Trans. Roy. Geol. Soc. Cornwall, Vol. 9, 1875, Penzance, pp. 167-176, pls. 1-4.
Two mines are included in the East Wheal Lovell namely, Tregonebris and Flatwork. In this article the tin deposit and the peculiarities of the latter mine are treated.

———. On a deposit of tin at Park of Mines.
Rep. Proc. Min. Ass. Cornwall and Devon for 1875 (1876), Falmouth, pp. 22-26, figs. 5.
Abstract: Rep. Brit. Ass. Adv. Sci., Vol. 45, 1876, London, p. 64. (Note and abs.)
Digest: Geol. Rec. for 1876, London, p. 12.
The tin-ore occurs as lenticular layers generally one or two inches thick, between the planes of bedding of the killas. The layers appear to be the off-shoots from north and south veins.

———. On the Great Flat Lode of Redruth and Camborne and some other tin deposits formed by the alteration of granite.
Quart. Journ. Geol. Soc. London, Vol. 34, 1878, London, pp. 640-653, figs. 10, pls. 30.
Plan and section of tin mines on Great Flat Lode.
Abstract: Rep. Brit. Ass. Adv. Sci., 1877, London, p. 71.
It is worked for three and one-half miles, and consists of a leader or true fissure vein only a few inches wide carrying tin and copper ores; a lode from 4 to 15 feet wide on one or both sides of the leader, mostly of tourmaline rock, carrying 1 to 3 per cent of tin; a capel of only slightly stanniferous tourmaline rock separates the lode from the slate or granite. There is an absence of wall or plane of separation between the lode and capel or the capel and granite. Thinks the lode and capel are altered granite, and that most of the lodes in Cornwall are of similar origin.

———. On some tin stockworks in Cornwall.
Quart. Journ. Geol. Soc. London, Vol. 34, 1878, London, pp. 654-659, figs. 3.
Abstract: Rep. Brit. Ass. Adv. Sci., 1877, London, p. 70.
Stockworks occur in killas (slate), granite and elvan (granite porphyry dikes). Gives a list of the stockworks occurring in each rock.

OX, CHAS. On a deposit of tin in Wendron.
Rep. Proc. Min. Ass. Cornwall and Devon, 1868, Truro, p. 35.
Not available to the authors.

ENGLAND (Continued)

388. FOX, ROBERT WEBB. On mineral veins.

4th Ann. Rep. Roy. Cornwall Polyt. Soc., 1836-1838, Falmouth, pp. 81-141, figs. 1-21, colored.

General description of tin and copper veins in Cornwall. Says that where tin and copper occur in the same vein, they are inclined to occur on opposite sides of the vein. Lodes said to be more productive when nearly vertical.

389. FRECHEVILLE, R. J. Notes on great main lode of Dolcoath, Cook's Kitchen, Tincroft, and Carn Brea mines.

Trans. Roy. Geol. Soc. Cornwall, Vol. 10, 1887, Penzance, pp. 146-156, colored plates 2, showing cross section of mines.

General description of tin-bearing veins in these mines, with figures of production and remarks as to the probable continuance of the vein.

390. ———. The results obtained by the Cornish system of tin-ore dressing.

Trans. Mg. Ass. Inst. Cornwall, Vol. 1, 1887, Camborne, pp. 96-104.

Reprinted in Eng. Mg. Journ., Vol. 40, 1885, New York, pp. 416-417.

An examination into the actual loss of black tin experienced in dressing.

391. FUCHS, E., et LAUNAY, L. DE. Traité des gîtes minéraux et métallifères.

Vol. 2, 1893, Paris, pp. 112-127. Maps, figs. and bibliography.

Tin deposits of Cornwall treated.

392. GARBY, JOHN. A catalog of minerals found in Cornwall with their localities.

Trans. Roy. Geol. Soc. Cornwall, Vol. 7, 1865, Penzance, p. 85.

Cassiterite, wood-tin, siliceous oxide and tin-pyrites given, the latter two unimportant.

GREG, R. P. and LETTSOM, W. G. *See* No. 1614.

393. GREGOR, WM. Observations on a remarkable change which metallic tin undergoes under peculiar circumstances, and on its partial conversion into a muriate of tin.

Trans. Roy. Geol. Soc. Cornwall, Vol. 1, 1818, Penzance, pp. 51-59.

"Some observations on a remarkable change which metallic tin undergoes that has long lain under the surface of the earth and on its partial conversion into a muriate."

394. HANCOCK, RICHARD. On the mineral deposits of Old Wheal Vor mine, Breage.

38th Ann. Rep. Roy. Cornwall Polyt. Soc., 1870, Falmouth, pp. 101-102.

This mine is situated in a basin of killas, between two granite hills and has produced more than £3,000,000 worth of tin and copper.

395. HAWKINS, C. Observations on gold found in the tin stream works of Cornwall.

Trans. Roy. Geol. Soc. Cornwall, Vol. 1, 1818, Penzance, pp. 235-236.

Notes that gold was frequently found with stream tin in a moor near the church of the parish of Ladock.

———. *See* No. 1395.

396. HAWKINS, JOHN. On submarine mines.

Trans. Roy. Geol. Soc. Cornwall, Vol. 1, 1818, Penzance, pp. 127-142.

An account of the early working of Huel Wherry tin mine, near Penzance. It was about 720 feet out from shore, barely uncovered at lowest tides, 19 feet under water at highest. Very rich ore. In dike 18' broad, 16' very rich. SnO_2 one of the constituent parts of the porphyry, so that it was called "stannified granite." 70,000 pounds of ore removed.

ENGLAND (Continued)

397. ———. On some remarkable phenomena attending the lodes of Polgooth tin mine.

Trans. Roy. Geol. Soc. Cornwall, Vol. 1, 1818, Penzance, pp. 143-153, pl. 5.

Description of the tin veins of Polgooth mine, which were observed by author or on which data were communicated to him, in 1791, by Capt. Phillips, director of mine, data being gathered as the working of mine opened it up.

398. ———. On the stratified deposits of tinstone, called tin-floors, and on the diffusion of tinstone through the mass of some primitive rocks.

Trans. Roy. Geol. Soc. Cornwall, Vol. 2, 1822, Penzance, pp. 29-48.

A description of the Cornwall tin deposits known as tin-floors is given, also an account of the form of deposit known in Germany as "stockworks" and methods used by Germans in working such deposits.

399. ———. Observations on the alluvial strata at Porth, Sandrycock and Pentuan.

Trans. Roy. Geol. Soc. Cornwall, Vol. 2, 1822, Penzance, pp. 285-289.

A paper in which the writer gives his views explanatory of alluvials of Porth and Sandrycock. Believes in deposition by a flood.

———. *See* No. 1396.

HEADDEN, WM. P. *See* No. 1617.

400. HELMHACKER, R. Allgemeines über das Zinnerzvorkommen in Cornwallis, nebst einigen speciellen Beispielen.

Oest. Zeitschr. Berg. Hütt., Vol. 27, 1879, Wien, pp. 427-429, 443-445, 458-460, 466-470, 473-475, 490-492, 500-503, 509-511, 524-527, 537-538, illus.

401. HENTY, G. M. On the occurrence of wood-tin at the great Wheal Vor mines.

Rep. Proc. Min. Ass. Cornwall and Devon, 1867, Falmouth, p. 55.

402. HENWOOD, GEORGE. Observations on certain tin stream works in the county of Cornwall.

Mg. Journ. Railw. Comm. Gaz., Vol. 22, 1852, London, pp. 607, 629; Vol. 23, 1853, p. 12. A series of three articles entitled the "Carnon," "Nancothan," and the "Bog," respectively treat of stream tin deposits, their situation, appearance, production, antiquities discovered in the course of working, animal and fossil remains, and methods of working. Theories as to the probable sources from which these great deposits were derived. Briefly treats of the character, superstitions and peculiarities of the Cornish miner.

403. ———. Four lectures on geology and mining.

1855, London.

(1) An introductory lecture, pp. 23; (2) Observations on certain tin stream works in the county of Cornwall, pp. 27; (3) On the metalliferous veins or lodes of Devon and Cornwall, and the methods of mining them, pp. 23; (4) On the manipulation of the ores of Devon and Cornwall, to render them marketable, pp. 21.

404. HENWOOD, W(ILLIAM) J(ORY). Deposits of stream tin ore in Cornwall with remarks on the theory of that formation.

Trans. Roy. Geol. Soc. Cornwall, Vol. 4, 1838, Penzance, pp. 57-69.

Overburden 14 to 53 feet. Gravel containing SnO_2, 4 to 18 feet, on granite bottom. Believes in diluvial deposition.

ENGLAND (Continued)

405. ———. On the metalliferous deposits of Cornwall and Devon.

Trans. Roy. Geol. Soc. Cornwall, Vol. 5, 1843, Penzance.

Treats of the quantity of tin mined in Cornwall and Devon; the form, displacement, and segregations of ore in the veins; the characteristics of tin veins in granite, slate and elvan; stream tin, wood tin and ordinary lode tin; and the minerals associated with cassiterite in the different country rocks.

406. ———. On a remarkable deposit of tin-ore at the Providence mines near St. Ives, Cornwall.

Trans. Roy. Geol. Soc. Cornwall, Vol. 7, 1865, Penzance, pp. 179-184.

London, Edinburgh, Dublin Philos. Mag. Journ. Sci., ser. 4, Vol. 4, 1852, Lond[illegible], pp. 538-541.

The Providence mines, in the parish of Lelant, comprise mines formerly kn[illegible] as Wheal Speed, Wheal Laity, Wheal Comfort and Wheal Providence. Observati[illegible] on the eastern workings in the slate and on the western within the granite for[illegible] tion, have already appeared in Trans. Roy. Geol. Soc. Cornwall, Vol. 5, Penzan[illegible], pp. 16-20. The intermediate tract now described is wholly granite.

407. ———. Observations on the metalliferous deposits of Cornwall.

Journ. Roy. Inst. Cornwall, Vol. 4, 1871-1873, Truro, pp. ix-xxxix.

Reprinted with alterations and additions in Rep. Proc. Min. Ass. Cornwall a[illegible] Devon, 1872-1873, Truro, pp. 1-20.

General description of veins of Cornwall, including tin-veins.

408. ———. On the detrital tin ore of Cornwall.

Journ. Roy. Inst. Cornwall, Vol. 4, 1871-1873, Truro, pp. 191-254. Read, May [illegible] 1873.

Abstracts: Geol. Mag. 1873, London, pp. 317-319; 1874, pp. 177-178.

Abstract translated by Zeiller, Ann. Mines, 7th ser. Vol. 6, 1874, Paris, [illegible] 114-130.

Contains summary of observations made at intervals during 45 years.

Four districts treated:

1. From Land's End to the eastern sources of Hayle River. 2. Included betwe[illegible] the Camborne, Crowan, Wendron and Constantine granite, and the eastern tri[illegible] taries of Restronguet, a creek of Falmouth. 3. Bounded on west by Truro Ri[illegible] and the Gannel, on east by Fowey and lower part of the Camel. 4. From east[illegible] part of third district to Tamar.

———. *See* Nos. 1327 and 1656.

409. Hill, J. B. Mining in southern district (Cornwall and Devon).

Summ. Progr. Geol. Surv. United Kingdom for 1902 (1903), London, pp. 38-4[illegible]

Although areas surveyed have been extensive mining districts, few mines a[illegible] still active. Tin streaming in original sense of the term, is practically a thin[illegible] of the past. Mines operated with modern machinery. Last few years the debris from mine burrows have been put under stamps, more especially those mines originally worked for copper.

410. ———. The plutonic and other intrusive rocks of W. Cornwall in their relation to the mineral ores.

Trans. Roy. Geol. Soc. Cornwall, Vol. 12, 1905, Penzance, pp. 546-615.

Tin always found in minute quantities in lithia micas, and except in lepidolite, copper also. Favors first deposition by ascending meteoric waters.

411. Hill, J. B., and MacAlister, D. A. Geology of Falmouth and Truro and of the mining district of Camborne and Redruth.

Mem. Geol. Surv. Great Britain, 1906, London, pp. 113-314, figs. 64.

Extracts: Min. World, May 11, 1907, p. 598; May 18, 1907, p. 626; June 1, 1907, p. 691.

Geology of districts is treated with particulars relating to the mines.

ENGLAND (Continued)

412. HUNT, ROBERT. A notice of the copper and tin raised in Cornwall.
Mem. Geol. Surv. Great Britain, Vol. 1, 1846, London, pp. 510-519.
Several tables given showing average production of various mines of Cornwall. Short early history of copper and tin production.

413. ———. The economic geology of Devonshire and Cornwall in 1868.
Journ. Bath West England Soc., n. s., Vol. 16, 1868, Bath, pp. 75-78.
Treats briefly of the early history of tin, tin trade from 1858 to 1868, and manner of working the mines at the time of writing.

414. ———. On the mineral production of Cornwall and Devon.
Rep. Proc. Min. Ass. Cornwall and Devon, 1869, Truro, pp. 5-11.
Not available to the authors.

415. ———. British mining.
1884, London, pp. 1-944, illus. 230.
A treatise on the history, discovery, practical development and future prospects of metalliferous mines, including tin mines, in the United Kingdom.

———. *See* Nos. 1397, 1688.

HUTCHIN, H. W. Notes on tin dressing. *See* No. 1507a.

HUTCHINSON, A. *See* No. 1620.

JAMES, HENRY. *See* No. 1398.

416. JARS, G. Voyages Métallurigique.
Vol. 3, 1781, Paris, pp. 154-223.
Sur les mines d'étain des hautes montagnes de la Saxe, celles de la Bohême, et de la province de Cornouaille en Angleterre, années 1757 et 1765.

417. K——, W. Die Bergwerke von Devonshire und Cornwall.
Berg. Hütt. Zeit., Vol. 38, 1879, Leipzig, pp. 374-375.

418. KERL, BRUNO. Gewinnung von Zinnstein und Chinathon in der Carclacegrube bei St. Austel in Cornwall.
Berg. Hütt. Zeit. Vol. 21, 1862, Leipzig, pp. 82-83.

419. ———. Zinngewinnung in Cornwall.
Berg. Hütt. Zeit., Vol. 21, 1862, Leipzig, pp. 144-148.
Treated under the heads: Ore occurrences; preparation of the tin ore; metallurgy of tin.

420. KITTO, BENEDICT. On mineral veins.
37th Ann. Rep. Roy. Cornwall Polyt. Soc., 1869, Falmouth, pp. 48-52.
Treats of one of the oldest mines in Cornwall, the Great Work Mine, which is situated partly in the parish of Breage and partly in Germoe. The three principal lodes, Great Work, Wheal Breage and South Wheal Breage are described.

421. KUDERNATSCH, JOSEPH. Ueber die Gewinnung und Darstellung des Zinnes, insbesondere in England.
Jahrb. k. k. geol. Reichs., Vol. 3, 1852, Wien, pp. 173-175.
Also, Berg. Hütt. Zeit., Vol. 12 (n. f. 7), 1853, Leipzig, pp. 162-164.

LE GRICE, C. V. *See* No. 1518.

ENGLAND (Continued)

422. LEIFCHILD, JOHN R. Cornwall, its mines and miners, with sketches of scenery. Designed as a popular introduction to metallic mines.

1855, London, pp. 303.

A readable popular account of the scenery and mines of Cornwall, including both alluvial and lode tin mines, with a short summary of foreign tin mines known at the time. Contains a general account of the geology of the Cornish tin mines, including the faulting. It also covers, in a general way, the manner of operating the mines and metallurgical processes used. Gives cost of operating, production and wages.

422a. LINGTON, T. Dolcoath copper and tin mine, Cornwall.

Mg. World, Vol. 32, 1910, Chicago, p. 107.

Treated geologically, also gives figures showing ore raised, outlay and profit.

LEWIS, GEORGE RANDALL. *See* No. 1402.

423. LOBLEY, J. LOGAN. Two days in a mining district.

Proc. Geol. Ass., Vol. 2, 1873, London, pp. 45-60.

Copper and tin mining district of East Cornwall is described. List of Cornish metallic minerals given. "All the Cornish tin is procured from the peroxide, for although tin pyrites or cupreous sulphuret of tin does occur in Cornwall, it is rare and not used for the production of metal."

424. LOCK, C. G. WARNFORD.

Economic Mining, 1895, New York, pp. 622-623.

Treats of Cornish tin.

LOUIS, HENRY. *See* No. 1340.

LOWER, T. *See* 489a.

425. MACALISTER, DONALD A. Vertical distribution of the commercially valuable ores in the Camborne lodes.

Summ. Progr. Geol. Surv. United Kingdom for 1903 (1904), London, pp. 26-28.

426. ———. A cross section and some notes on the tin and copper deposits of Camborne, with special reference to the limits of productive ore ground.

Trans. Roy. Geol. Soc. Cornwall, Vol. 12, 1905, Penzance, pp. 773-795, figs. 5.

427. ———. Geological aspect of the lodes of Cornwall.

Econ. Geol., Vol. 3, 1908, Lancaster, pp. 363-380. Geol. map.

Gives a short historical summary of the Cornish mines and their yield from early times. He then treats the general geology, the lodes, their structure and relations to the granite. The pneumatolytic and metasomatic action of vein forming solutions is treated with regard to granite, slate and greenstone. The genesis of the ores is ascribed to the solutions from a cooling granitic magma. The alluvial tin deposits are briefly described.

———. *See* Nos. 449, 1659.

428. MACLAREN, J. MALCOLM. The occurrence of gold in Great Britain and Ireland.

Trans. Inst. Mg. Eng., Vol. 25, 1903, London and Newcastle-upon-Tyne, pp. 428-429, 440, 494.

ENGLAND (Continued)

The occurrence of gold in the tin placers of Cornwall is described. 3½ pounds of tin ore gotten from 150 pounds of gravel in Goldmine River, County Wicklow, Ireland. All wood-tin. Accompanied by magnetite, ilmenite, hematite, iron-pyrites, galena, wolframite, molybdenite, gold, copper-pyrites and oxides of manganese. Cassiterite was in grains up to ½ inch in diameter.

MACLEAN, JOHN. *See* No. 1403.

429. Maps of the Geological Survey of Great Britain.
Show tin-bearing veins and placers. Published previous to 1869.

430. MARTIN, JOSEPH S. The position and prospects of Cornish mining.
Coll. Guard., Vol. 77, 1899, London, p. 943.
Notes from the author's annual report on the southwestern district for 1898. Urges that the mines be more properly equipped and wisely managed.

431. MAYNARD, JOHN. Remarks on two cross-sections through Carn Brea Hill and the neighboring mines.
Rep. Proc. Min. Ass. Cornwall and Devon, 1873-1874, Falmouth, pp. 43-54; pls. 9.
Sections through the principal tin mines and the intervening country.

432. MERRET, C. A relation of the tinn mines and working of tinn in the county of Cornwall.
Philos. Trans. Roy. Soc. London, No. 138, Vol. 12, 1678, London, pp. 949-952.
Philos. Trans. abridged, Vol. 2, 1809, pp. 424-426.
Description of the manner of occurrence of tin ore, and brief account of methods of smelting.

433. MOISSENET, LÉON. Du minerai d'étain dans le Cornwall.
Ann. Mines, ser. 5, Vol. 14, 1858, Paris, pp. 77-276.
Brief abstract in Neues Jahrb. Min., 1860, Stuttgart, p. 360.
Sketch of Cornwall; description of tin veins and associated minerals; description of the working of the mines and economic results.

434. ———. Étude sur les filons du Cornwall et du Devonshire.
C. R. Acad. Sci., Vol. 55, 1862, Paris, pp. 759-762.
Ann. Mines, ser. 6, Vol. 3, 1863, Paris, pp. 161-171.
Mg. Smelt. Mag., Mo. Rev. Pract. Mg. Quarry. Met., Vol. 3, 1863, London, pp. 20-23 and Vol. 4, 1864, p. 25.

435. MOISSENET, L. L. Observations on the rich parts of the lodes of Cornwall.
Translated by J. H. Collins, 1877, London.
Not available to the authors.

MYRICK, C. M. *See* No. 1541.

436. NEWLAND, D. H. Tin in United Kingdom.
Min. Ind. for 1902, Vol. 11, 1903, New York and London, p. 595.
Review of tin industry in Cornwall during 1902.

437. ———. Tin in Cornwall.
Min. Ind. for 1903, Vol. 12, 1904, New York and London, pp. 332-333.
Review of tin mining in Cornwall during 1903.

ENGLAND (Continued)

438. OXLAND, R. The mineral resources of Devon and Cornwall.
Ann. Rep. Trans. Plymouth Inst., Devon and Cornwall Nat. Hist. Soc., Vol. 5, 1873-1874 (1874), Plymouth, pp. 485-493.
Not available to the authors.
At time of writing article, there was a great depression in Cornish tin and copper mining on account of market conditions. The article is an inquiry into the possibility of reviving the mining industries.

439. PARIS, JOHN AYRTON. A guide to Mount's Bay and the Land's End.
1824, London, 2d Ed.
Contains many semi-scientific allusions to the tin mines of Cornwall, with points concerning their history, origin of names, etc.

PEARCE, GILBERT B. *See* No. 1407.

440. PEARCE, RICHARD. Notes on the occurrence of cobalt in connection with the tin ores of Cornwall.
Journ. Roy. Inst. Cornwall, No. 13, Vol. 4, 1872, Truro, pp. 81-83.
Author found an appreciable quantity of cobalt in a sample of dressed tin ore (black tin) from Dolcoath mine. Analysis of "hard-head" showed 4.40 per cent cobalt and 16.25 per cent tin. Concludes that cobalt might be extracted profitably from "hard-head" and at same time afford a means for recovery of large portion of tin which was then lost.

441. ———. The anniversary address of the president.
Trans. Roy. Geol. Soc. Cornwall, Vol. 13, pt. 2, 1906, Penzance, pp. 97-112.
Discussion of Cornwall's mineral resources and their future.

———. *See* No. 1629.

PENBERTHY, JOHN. *See* No. 467.

442. PHILLIPS, J. ARTHUR. The rocks of the mining districts of Cornwall, and their relation to metalliferous deposits.
Quart. Journ. Geol. Soc. London, Vol. 31, 1875, London, pp. 319-345, pl. 16.
Gives a description both from macroscopic and microscopic examination of the rocks in which mineral deposits occur in Cornwall, with analyses of a number of them. Also discusses the mineral deposits including tin.

———. *See* No. 1632.

PHILLIPS, J. A., and LOUIS, H. *See* No. 1350.

443. PHILLIPS, WM. On the veins of Cornwall.
Trans. Geol. Soc. London, Vol. 2, 1814, London, pp. 110-160.
History and description of veins of Cornwall, including the Tincroft mine.

PHILLIPS, WILLIAM. *See* No. 1633.

PLINIUS, CAIUS. *See* No. 1408.

POLWHELE, R. *See* No. 1409.

444. PRYCE, WILLIAM. Mineralogia Cornubiensis. A treatise on minerals, mines and mining: Containing the theory and natural history of strata, fissures and lodes, with the methods of discovering and working of tin, copper and lead mines, and of cleansing and metallizing their products.

ENGLAND (Continued)

showing each particular processing for dressing, assaying and smelting of ores, to which is added an explanation of the terms and idioms of miners.

1778, London, pls. 7, tables 2, portrait of author, pp. 331.
Extract: Journ. Mines, No. 3, Vol. 1, 1795, Paris, pp. 91-126.

45. PUNNETT, H. MACAULAY. On some peculiar deposits of tin in St. Aubyn and Grylls mine.

Trans. Roy. Geol. Soc. Cornwall, Vol. 7, 1865, Penzance, pp. 379-380.
A brief inquiry into the nature of the contents of peculiar shoots of tin ore. The ore is said to be different in chemical character from the tin ore in the main lode.

RAMMELSBERG, C. *See* No. 1637.

46. RANCE, CHAS. E. DE. On the relative age of some valleys in the north and south of England, and of the various and post-glacial deposits occurring in them.

Proc. Geol. Ass. London, Vol. 4, 1876, London, p. 250.
Thinks stream tin deposits of South England are nearly synchronous with the West Lancashire post-glacial marine beds. Points out that there has been no glaciation in this region.

47. RASHLEIGH, P. An account of the alluvial deposition at Sandrycock.

Trans. Roy. Geol. Soc. Cornwall, Vol. 2, 1822, Penzance, pp. 281-284.
Drawn up in 1792, communicated by J. Hawkins in 1819.
"Tin ground and loose stones of all sorts" from one foot to 6 feet thick overlain by 35 feet overburden.

RAY, JOHN. *See* No. 1554.

48. REID, CLEMENT, and FLETT, J. S. The geology of the Land's End district.

Explanation of sheets 351 and 358, with contributions by Wilkinson, B. S. N., Dixon, E. E. L., Pollard, W. and a mining appendix by MacAllister, D. A..
Mem. Geol. Surv. Great Britain, 1907, London, p. 158, figs. 35, pls. 6.
Geology of district and mines, and their output of tin since 1852.

49. REID, CLEMENT, and SCRIVENOR, J. B. The geology of the country near Newquay.

Mem. Geol. Surv. Great Britain, 1906, London, pp. 72-80, and pp. 91-106, with map and figs.
Gives estimates of the amount of tin produced. Former work for stream-tin, now long ceased. Describe briefly the mines now working near St. Agnes, and some of those that are abandoned. Describe the microscopic appearance of the tin lodes. Also describe the geology of the lodes at Cligga head.
D. A. McAllister gives notes on the particular mines, their ores and geology on pp. 91-106, with figs.

———. *See* No. 1638.

50. REYER, E. Zinn.

1881, Berlin, pp. 102-156, figs. 3.
Treats under heads: Geologische Beschreibung; die Erzgänge; Geschichte der Zinnproduktion und des Zinnhandels von Cornwall.

50a. RICKARD, THOMAS. Fifty years in Cornwall.

Mg. Sci. Press, Vol. 100, 1910, San Francisco, pp. 795-797.

ENGLAND (Continued)

Reviews the improvements in technical methods and appliances in Cornwall mining, and concludes that this improvement has not been inadequately translated into economic results.

451. ROWE, T. P., and FOSTER, C. LE NEVE. Observations on Balleswidden mine.

Trans. Roy. Geol. Soc. Cornwall, Vol. 10, 1887, Penzance, pp. 10-17.

Short description of Balleswidden mine, situated about 1 mile from village of St. Just-in-Penwith, which was abandoned in 1873. During the 36 years that the mine was worked, more than 12,000 tons of black tin were sold, valued at £694,094.

452. RUDLER, F. W. Handbook to minerals of the British Islands.

1905, London.

Cassiterite and its associates, pp. 5-32.

Treats not only of cassiterite and stannite, with their accompanying minerals, but of the origin, form and other characteristics of the veins in which they are found.

453. SALMON, ARTHUR L. Cornwall.

1903, London, pp. 16-21.

A short general description of tin-mining in Cornwall, adapted to the needs of tourists not particularly interested in the subject.

454. SALMON, H. C. The mines and mining operations of Cornwall.

Mg. Smelt. Mag. Mo. Rev. Pract. Mg. Quarry. Met., Vol. 5, 1864, pp. 257, 328.

Not available to the authors.

SAUNDERS, C. D. *See* No. 1414.

SCRIVENOR, J. B., and REID, CLEMENT. *See* No. 1638.

455. SIMMONS, WM. The metallic ores of Cornwall.

Proc. Liverpool Geol. Soc., Vol. 3, 1878, Liverpool, pp. 28-35.

Brief description of occurrences of the ores of tin, copper, iron and lead.

456. SKEWES, EDWARD. Red river tin stream, Cornwall.

Eng. Mg. Journ., Vol. 74, 1902, New York, pp. 178-180, figs. 5.

Abstract: Min. Ind. for 1902, Vol. 11, 1903, New York and London, p. 653.

An article discussing the mode of operation of the Cornish tin mines, the loss of tin, etc.

SMITH, GEORGE. *See* No. 1418.

457. SMYTH, WARINGTON W. Metallic mining (tin mines).

Brit. Mfr. Indust., Vol. 2, 1876, London, pp. 26-30.

Treats of the occurrence of copper and tin in certain districts of England.

SOLLY, R. H. *See* No. 1640.

SPARGO, T. *See* No. 1699.

458. STELZNER, A. W. Das Zinnerzvorkommen auf der Grube East Wheal Lovell in Cornwall.

Mitth. Verh. Bergmänn. Vereins zu Freiberg. Sitzg., Vol. 2, Nov. 1876.

Digest: Neues Jahrb. Min., 1877, Stuttgart, pp. 416-417.

Berg. Hütt. Zeit., Vol. 35, 1876, Leipzig, pp. 417-419.

Based on "The tin deposits of East Wheal Lovell" by C. Le Neve Foster, published in Trans. Roy. Geol. Soc. Cornwall, Vol. 9, 1875, Penzance, pp. 167-178.

First reference not available to the authors.

ENGLAND (Continued)

9. STEPHENS, FRANCIS J. Abstract of essay on the "Mineral resources of Falmouth."

54th Ann. Rep. Roy. Cornwall Polyt. Soc., 1886, Falmouth, p. 193.
Tin is mentioned as occurring at Pennance mine, Falmouth.

0. STEPHENS, F. J. The ancient tin mining districts of Cornwall.

72d Ann. Rep. Roy. Cornwall Polyt. Soc., 1904, Falmouth, pp. 101-114.
Notes on the geology, minerals and mines of Levant, St. Ives and Zennor.

1. STEPHENS, HUGH. Remarks on the mineral phenomena of Huel Rose in the parish of Sithney.

Rep. Proc. Min. Ass. Cornwall and Devon, 1871 (1872), Truro, pp. 47-49.

2. SYMONS, BRENTON. Treatise on the geology of Cornwall.

1884, Penzance.
Not available to the authors.

3. SYMONS, R. On Carclaze tin and china clay pit.

Journ. Roy. Inst. Cornwall, Vol. 6, 1881, Truro, pp. 140-143, map 1.
Describes in a general way Carclaze mine which yielded 10 to 12 tons of tin ore per year from small veins in a decomposed granite (growan). Had for many years produced large quantities of china clay and workings covered over 15 acres.

4. TAYLOR, CHAS. D. Description of the tin stream works in Restronguet Creek near Truro.

Proc. Inst. Mech. Eng. for 1873, Birmingham, pp. 155-166, pls. 58-59.
Discussion 162-166.
Extracts: Bull. Soc. Indust. min., ser. 2, Vol. 4, 1875, Saint Étienne, pp. 678-680. Berg. Hütt. Zeit., Vol. 35, 1876, Leipzig, pp. 443-444.
Description of methods used in recovering "a valuable deposit of stream tin which is found under the water in Restronguet Creek, and lies on the rock beneath the mud and silt that form the bottom of the creek."

TAYLOR, J. *See* No. 1663.

TAYLOR, JOHN. *See* Nos. 1419, 1576.

THIOLLIER, M. A. *See* No. 1579.

5. THOMAS, CHAS. Remarks on mining in Cornwall and Devon.

22d Ann. Rep. Roy. Cornwall Polyt. Soc., 1854, Falmouth, pp. 28-35.
Treats of the geological and mineralogical character of the rocks that have been found most productive of metallic ores.

6. THOMAS, C. Mining fields of the West, Cornwall and Devon. 1867.

Not available to the authors.

7. THOMAS, HERBERT. Cornish mining interviews. Underground scenes by J. C. Burrows.

1896, Camborne, pp. 351.
Treats of tin mining in a popular way, and contains an interview with Capt. John Penberthy on "Bolivia as a tin-producing country and its probable effect on Cornwall" (pp. 1-8).
The illustrations are good and have been widely reprinted. See 320 and 475.

ENGLAND (Continued)

468. ———. The mineralogical constitution of the finer material of the Bunter pebble-bed in the west of England.

Quart. Journ. Geol. Soc. London, Vol. 58, 1902, London, p. 623.

Paragraph on cassiterite "Difficult to distinguish from rutile, but it occurs in small quantity in the heavy residues from some of these sands. Seem to be two modes of occurrence: (I) in pale-yellow, well-shaped crystals, and (II) in more or less rounded brownish grains."

469. THOMAS, JOSIAH. Description of the operations at Dolcoath mine.

Journ. Roy. Inst. Cornwall, Vol. 3, No. 11, 1870, Truro, pp. 191-197.

An account of the mine, and manner of working it. Author states that at time of writing he believes "we are working to a greater depth, and raising a larger quantity of tin, as well as making greater profits, than any other tin mine in the world.

"The mine has been producing of late about 87 tons of black tin per month, or 1050 tons per year."

470. ———. Description of Dolcoath main lode, illustrated by transverse section, and specimens from the lode and country.

Rep. Proc. Min. Ass. Cornwall and Devon, for 1882 (1883), Truro, pp. 13-15.

Dolcoath is the deepest metalliferous mine in Cornwall. The granite has become softer, and the tin lodes larger and more productive with depth; mine shows no sign of decay.

471. THOMAS, R. Report on a survey of the mining district of Cornwall, from Chasewater to Camborne.

1819, London.

Not available to the authors.

472. THOMAS, R. A. Notes on Cornish mines in 1896.

64th Ann. Rep. Roy. Cornwall Polyt. Soc., 1896, Falmouth, pp. 89-94.

Discussion of the decreased tin output of Cornwall, and of means for its increase.

THOMAS, R. ARTHUR. *See* No. 1666.

473. THOMAS, RICHARD A. Some observations on the "Great Flat Lode" in Wheal Uny mine, near Redruth.

54th Ann. Rep. Roy. Cornwall Polyt. Soc., 1886, Falmouth, pp. 184-188. 1500 words.

Calls Great Flat Lode a "true fissure vein," but says it reaches 72 feet (12 fathoms) in width with a small amount of tin distributed evenly through it. Dip varies. Slickensides occur where vein narrows. Many "cross-courses" break up the vein. Generally dips to the west. Occasionally rich enough to work 30 feet wide. Copper ores in upper part of vein and some chalcopyrite below.

474. THOMAS, WM. Excursion to Cornwall.

Proc. Geol. Ass., Vol. 10, 1887, London, pp. 196-215, figs. 7.

Mentions a few general points about Carclaze, Carn Brea and other tin mines.

475. THOMAS, WM., and BURROWS, J. C. 'Mongst mines and miners, underground scenes by flashlight.

1883, London and Camborne, pp. 32, pls. 26. Colored section of Dolcoath main lode, 62½ fathoms per inch.

Written in popular style. The plates are excellent. See 467.

476. TREDINNICK, R. Tin and tin mining.

Mg. Journ. Railw. Comm. Gaz., Vol. 46, 1876, London, p. 1388.

General article giving amount of ore raised and profits derived from some of the Cornwall mines.

ENGLAND (Continued)

. TREGASKIS, JAMES. Remarks on the geology of Cornwall and Devon in connection with the deposits of metallic ores and on the bearing of productive lodes.

(Two lectures.) 1857, Redruth.
Not available to the authors.

. TWEEDY, W. M. Notices of minerals of uncommon occurrence recently found in Cornwall.

21st Ann. Rep. Roy. Inst. Cornwall, 1841 (1842), Truro, pp. 38-39.
Among other minerals which author mentions as uncommon are wood-tin and detached crystals of tinstone and sandstone in the form of crystals of feldspar.

. ———. A description of the Lode at Wheal Coates Mine, in which the pseudomorphous crystals of tin occurred.

27th Ann. Rep. Roy. Inst. Cornwall, 1845, Truro, pp. 20-24.
Mineralogical and geological description of the tin deposits at Wheal Coates, with detailed descriptions of individual pseudomorphs of cassiterite after feldspar.

TYLOR, A. *See* No. 1420.

. UNWIN, GEORGE. Letters, remarks, etc., with a view to open an extensive trade in the article of tin from the county of Cornwall to India, Persia and China.

1790, London.
Not available to the authors.

. USSHER, W. A. E., and MACALISTER, D. A. Summary of progress of the geological survey of the United Kingdom.

Mem. Geol. Surv. Great Britain for 1903 (1904), London, pp. 22-23, 26-28.
Report on the progress of tin mining in Cornwall for year 1903.

a. VIVIAN, JOSEPH. Reminiscence of mining in Cornwall.

Mg. Sci. Press, Vol. 100, 1910, San Francisco, pp. 743-745, map.
Treats of the early history of copper and tin mining in Cornwall.

. WAIT, F. W. The tin mines of Cornwall.

Mg. Journ. Railw. Comm. Gaz. Vol. 54, 1884, London, p. 1423.
Report of a lecture delivered before the Menai Society. Begins with the early history of tin in Cornwall, tracing it down to the present time. Gives description of principal mines. Treats of tin itself, the manner of occurrences and working. The Cornish miner, his habits, characteristics and mining methods, with the difficulties encountered. Popular.

a. WALKER, EDWARD. The Red River, Cornwall.

Mg. Sci. Press, Vol. 97, 1908, San Francisco, p. 849. Map of Cornwall.
An account of the trouble caused in the Red River due to the tailings from the tin mines.

WARNER, RICHARD. *See* No. 1421.

. WATSON, J. Y. A compendium of British mining, with statistical notices of the principal mines in Cornwall; to which is added . . . . a glossary of the terms and usages of mining. London, 1843.

Mg. Journ. Railw. Comm. Gaz., Vol. 21, 1851, London, pp. 3, 22, 27, 39, 50, 62.
Treated under heads: General features of a mine; on the nature of veins; the nature of lodes; the system of Cornish mining; on "bounding."
Reprinted with revisions and corrections up to 1851.

ENGLAND (Continued)

484. WEBB, —, and GEACH, —. History and progress of mining in the Caradon and Liskeard district.

Not available to the authors.

WEEKS, JOSEPH D. *See* No. 1372.

485. WEST, H. E. Cornish tin mining.

Mg. Sci. Press, Vol. 94, 1907, San Francisco, pp. 179-181, 213-214.

486. WHITE, W. T. The south or main tin lode of Wheal Peevor.

Trans. Min. Ass. Inst. Cornwall, Vol. 1, 1887, Camborne, pp. 81-84.

A description of a tin lode with its faulting. At one place the throw is 75 fathoms.

487. WILLIAMS, ARCHIBALD. The romance of mining. The tin mines of Cornwall.

London and Philadelphia, 1905, pp. 258-273.

A popular and fairly accurate account of tin mining in Cornwall.

488. WILLIAMS, JOHN. Account of some remarkable disturbances in the veins of the mine called Huel Peever, in Cornwall.

Trans. Geol. Soc. London, Vol. 4, 1817, London, pp. 139-145.

Huel Peever contains numerous examples of almost every species of interruption known to Cornwall veins. Its tin vein was so heaved by other veins that it was not again discovered for forty years. Describes the disturbed condition of the veins.

489. WILLIAMS, R. H. Occurrence of tin in the St. Austell district.

Mg. Journ. Railw. Comm. Gaz., Vol. 80, 1906, London, pp. 276-277, 1200 words.

"A review of this district in Cornwall, England, describing the geological structure."

489a. WOODWARD, J(OHN). A catalogue of English native fossils in the collection of J. Woodward, M. D.

1728, London, 3 vols., bound together. Vol. I, pp. 198-206. Vol. III, pp. 40-41.

In the first reference 30 specimens of Cornish tin ores are briefly described with short, quaint descriptions, written by T. Lower, of most of the mines from which they came.

In the third volume, which treats of foreign specimens, 18 specimens of tin ore from Saxony and Bohemia are noted.

WORTH, R. N. *See* Nos. 1425, 1426, 1427.

490. ZIRKEL, FERDINAND. Bergmännische Mittheilungen über Cornwall.

Zeitschr. Berg. Hütt. Sal. preuss. Sta., Vol. 9, 1861, Berlin, pp. B 242-261, figs. 4.

Treated under the heads: Ore in Cornwall, dressing, metallurgy and product[illegible].

EUROPE

ROLKER, CHAS. M. *See* No. 1357.

See under Austria (Bohemia), England (Cornwall and Devonshire), France, Germany, Ireland, Italy, Norway, Portugal, Russia, Scotland, Spain, Sweden.

FINLAND

See under Russia.

FRANCE

491. ANONYMOUS. Apperçu de l'extraction et du commerce des substances minérales en France avant la Révolution.

Journ. Mines, Vol. 1, No. 1, 1794-1795, Paris, pp. 72-73.

Notes a report by M. Schreiber on the finding of bits of metallic tin in Pieux, Manche, France.

492. ———. Ueber die Auffindung des Zinns in Frankreich.

Tasch. ges. Min. für 1815, Vol. 9, II, Frankfort-am-Main, pp. 560-562.

Brief account of the discovery of tin veins in France in 1809.

493. ———. Tin mines in France.

Mg. Journ. Railw. Comm. Gaz. Vol. 1, 1835, London, p. 53.

Tin was not known to exist in France until 1809, and it was not until 1817 that a deposit was discovered. This was found by a marine officer, and Dufrénoy was sent to examine it. The tin ore occurs at the junction of granite and slate and the country bears a marked resemblance to Cornwall.

494. ———. Tin in Montebras, France.

Min. Ind. for 1899, Vol. 8, 1900, New York and London, p. 621.

Deposits of tin at Montebras are at contact of granite and feldspathic porphyry. Ore said to average 4 per cent, which would be above the grade of other European deposits.

495. ———. Tin in France.

Min. Ind. for 1901, Vol. 10, 1902, New York and London, pp. 637-646.

Small veins carrying cassiterite are known to occur near Vaulry and have been worked from time to time. Recently a company, the Société des Mines de Vaulry et Cieux, secured a concession of alluvial ground near by, and some ore is being produced.

496. ———. The mines of Montebras.

Mg. Journ. Railw. Comm. Gaz. Vol. 84, 1908, London, p. 3.

A very general description of the developments, dressing plants, and tin deposits at Montebras in central France.

Antimony, amblygonite and montebrasite occur with tin ore said to average 2 per cent cassiterite.

497. AUDIBERT, E. Sur le gîte d'étain oxydé de Maupas, Morbihan.

Ann. Mines, ser. 4, Vol. 7, 1845, Paris, pp. 181-186.

Review in Neues Jahrb. Min. 1847, Stuttgart, pp. 358-360.

Description of tin veins of Maupas, France.

498. BAUDOT, F. Les mines d'étain de la Villeder (Morbihan).

Bull. Soc. Indust. min., ser. 3, Vol. 1, Livre 1, 1887, Saint Étienne, pp. 151-187.

Treats of the situation and size of the concession; history of the discovery of the veins and their former working by the Romans, and other attempts at working the veins. Describes the working of alluvial deposits of the locality, and geology. States that pyrite, mispickel, sphalerite, galena, quartz, emerald, muscovite and plogopite micas, gilbertite, tourmaline, topaz and feldspar are found with the cassiterite, all of which are described at some length, as are the veins. Much space is given to a description of the working of the mine, its machinery, etc.

BECK, RICHARD. *See* No. 1299.

499. BLAVIER, ED., and LORIEUX, T. Sur un gîte d'étain nouvellement découvert, à la Villeder (Morbihan).

Ann. Mines, ser. 3, Vol. 6, 1834, Paris, pp. 381-388.

FRANCE (Continued)

500. BURTHE, M. P. L. Note sur les travaux de recherche exécutés à Meymac, (S. France).

Ann. Mines, ser. 9, Vol. 12, 1897, Paris, pp. 5-31.
Extract: Zeitschr. prakt. Geol., 1897, Berlin, pp. 418-420.
Deposit not important from commercial standpoint, but, geologically, has attracted attention because of peculiarities. The deposit is described in detail.

501. COTTA, BERNARD VON. A treatise on ore deposits.

Translated by F. Prime, Jr., 1870, New York, pp. 380-384.
Treats of tin deposits of Brittany.

502. CRESSAC, C. DE. Die Entdeckung des Zinns in Frankreich.

Ges. Nat. Freunde Berlin Mag. neust. entd. ges. Nat., Vol. 4, 1810, Berlin, pp. 239-240.

503. CRESSAC, C. DE. Notice sur la découverte de l'étain en France.

Journ. Mines, No. 198, Vol. 33, 1813, Paris, pp. 435-452.
(1) Reconnaissance et indication d'un second gisement d'étain dans le département de la Haute-Vienne.
(2) Traduction littérale de l'indication du gisement d'étain reconnu par le mineur saxon Schnor de Schnéeberg.
(3) Reconnaissance et indication d'un troisième gisement d'étain dans le département de la Haute-Vienne.

D———, C. H. *See* No. 1386.

D'ACHIARDI, ANTONIO. *See* No. 1313.

504. DAUBRÉE, AUGUSTE. Note sur le kaolin de La Lizolle et d'Échassières, département de l'Allier, et sur l'existence de minerai d'étain qui y a été exploité à une époque extrêmement reculée.

C. R. Acad. Sci., Vol. 68, 1869, Paris, pp. 1135-1139.

———. *See* Nos. 1314 and 1316.

DAVIES, D. C. *See* No. 1317.

505. DAVY, L. Sur l'ancienneté probable de l'exploitation de l'étain, en Bretagne.

C. R. Acad. Sci., Vol. 125, 1897, Paris, pp. 337-339.
Abstract: Lébesconte, P., Bull. Soc. sci. méd. Ouest, Vol. 7, 1898, Rennes, pp. 51-53.
Found slag with small grains of crystalline tin near old excavations. Considered to be product of ancient smelting. Found veins near by containing tin. Veins cut upper Silurian metamorphic rocks. They consist of quartz with muscovite, cassiterite, tourmaline, etc. Cassiterite where vein is most micaceous. Thinks work was done by Gauls before Roman conquest. Location: between Abbaretz and Vay in Lower Loire.

506. DUFRÉNOY, P. A. Sur le plateau central de la France, et particulièrement sur les terrains secondaires qui recouvrent les pentes meridionales du massif primitif qui le compose.

Ann. Mines, ser. 2, Vol. 3, 1828, Paris, pp. 55-57.
Short account of the occurrence of tin in granite and gneiss in France.

FRANCE (Continued)

507. DUFRÉNOY, PIERRE ARMAND, et JUNCKER. Rapport sur les recherches et les essais de la mine d'étain de Piriac, département de la Loire Inférieure.

Ann. Mines, Vol. 4, 1819, Paris, pp. 21-58. (See No. 513.)

508. DUROCHER, M. J. Observations sur les dépôts stannifères de la Bretagne et sur les métaux précieux qu'ils renferment.

C. R. Acad. Sci., Vol. 32, 1851, Paris, pp. 902-904, Vol. 45, 1857, pp. 522-525.
Digest: Neues Jahrb. Min., 1852, Stuttgart, pp. 498-499.

509. FUCHS, E., et LAUNAY, L. DE. Traité des gîtes minéraux et métallifères.

Vol. 2, 1893, Paris, pp. 101-158.
A general article upon the tin deposits of the world with an especially good description of the French tin deposits at La Villeder, Montebras, Creuse, Vaulry, Cieux, Colettes (Allier), Chanteloube and St. Leonard. Gives general geology and list of accompanying minerals at each place.

510. GOUVENAIN, C. A. DE. Sur la dissémination de l'étain et sur la présence du cobalt et de diverses autres substances dans les kaolins des Colettes et d'Échassières situés dans le département de l'Allier.

C. R. Acad. Sci., Vol. 78, 1874, Paris, pp. 1032-1034.

511. GUÉDRAS, MARCEL. Sur la presence de l'étain dans le département de la Lozére.

C. R. Acad. Sci., Vol. 138, 1904, Paris, p. 1121.
Digests: Trans. Inst. Mg. Eng., Vol. 27, 1903-1904 (1905), London and Newcastle-upon-Tyne, p. 629.
Mg. Journ. Railw. Comm. Gaz., Vol. 75, 1904, London, p. 574.
Neues Jahrb. Min., 1906, I (Ref.), Stuttgart, p. 332.
Though department of Lozére is rich in metalliferous veins, tin ore has not hitherto been recorded there. Author discovered a vein close to Great Monastier fault, in parish of Barjac. Country rock is mica schist, vein dips 60°, and is 7½ feet thick at outcrop. The gangue consists chiefly of barytes and quartz; between these is a thin band of cassiterite barely 1 inch thick with which are closely associated pyrolusite and wolframite.

512. HERSART, CH. Sur une nouvelle découverte de minerai d'étain dans le département de la Loire-Inférieure.

Journ. Mines, Vol. 35, No. 208, 1814, Paris, pp. 293-308.

513. JUNCKER, —, et DUFRÉNOY, P. A. Rapport sur les recherches et les essais de la mine d'étain de Piriac, département de la Loire Inférieure.

Ann. Mines, Vol. 4, 1819, Paris, pp. 21-58.
Review: Tasch. ges. Min. 1824, Vol. 18, III, 1824, Frankfurt-am-Main, pp. 676-678. (See No. 507.)

514. KERFORNE, F. Découverte d'un gisement d'étain et de wolfram dans l'Ille-et-Vilaine.

Bull. Soc. sci. méd. Ouest., Vol. 11, 1903, Rennes, pp. 448-449.
Trav. Sci. Univ. Rennes, Vol. 2, 1903, Rennes, pp. 380-381.
Digest: Neues Jahrb. Min., 1905, II (Ref.), Stuttgart, p. 369.

515. KERNDT, C. H. THDR. Ueber die neueren Zinngruben zu Piriac.

Polyt. Centr., 1858, Leipzig, pp. 86, 106, 168.
Not available to the authors.

FRANCE (Continued)

516. LACROIX, A. Minéralogie de le France et de ses colonies. Description physique et chemique des minéraux. Étude des conditions géologiques de leurs gisements.

1901, Paris. Cassiterite. Tome 3, pp. 217-235.

Crystallization and general description of cassiterite, pp. 217-220. In granites, Bretagne (Loire Inférieure), Plateau Central, p. 221. In quartz veins, pp. 221-251: Bretagne, pp. 223-227. Finistere, p. 223. Morbihan, pp. 223-227. Loire Inférieure, p. 227. Anjou, pp. 227-231. Maine-et-Loire, p. 227. Creuse, pp. 228-229. Correze (Meymac), pp. 229-230. Haute-Vienne, pp. 230-231. Charente, p. 231. Puy-de-Dôme, p. 231. Allier, p. 231. Maures, Congo (10 words), Madagascar, Tonkin, p. 231. In veins with sulphides, Indochine (Laos), pp. 231-233. Alluvial deposits, pp. 233-235. Bretagne (Morbihan & Loire Inférieure), pp. 234-235. Plateau Central (Haute-Vienne & Creuse), p. 235. An excellent article treating cassiterite from the mineralogical standpoint.

517. LASSALLE, TH. Mines d'étain en France.

Métallurgie, Vol. 31, 1900, Paris, pp. 343, 345.

Tin deposits of Montebras are on contact of granite and feldspathic porphyry. Ore said to average 4 per cent, which would be above the grade of other European deposits.

518. LAUNAY, L. DE. Une mine de lithine en France.

La Nature, 2d ser., No. 1464, Vol. 29, 1901, Paris, pp. 43-44.

Digest: Geol. Centr., Vol. 1, 1901, Leipzig, p. 707.

"Le gisement d'étain de Montebras déjà exploité par les anciens gaulois, fournit surtout maintenant de l'amblygonite (phosphate d'alumine et fluorure double de soude et de lithine) qui est utilisée pour la préparation des sels de lithine. Cette substance est accompagnée d'apatite et de plusieurs minéraux rares, tels que le niobium, la wavellite, l'urane, etc."—L. Pervinquière.

519. LIMUR (le comte), DE. La mine d'étain de la Villeder.

Bull. Soc. Hist. nat. Toulouse, Vol. 16, 1882, Toulouse, pp. 247-261.

520. LODIN, —. Note sur la constitution des gîtes stannifères de la Villeder (Morbihan).

Bull. Soc. geol. France, ser. 3, Vol. 12, 1884, Paris, pp. 645-666, map 1, figs. 2.
Review: Neues Jahrb. Min., 1885, II (Ref.), Stuttgart, pp. 58-59.

521. ———. Étude sur les gîtes métallifères de Pontgibaud (France).

Ann. Mines, ser. 9, Vol. 1, 1892, Paris, pp. 471-472.

LOUIS, HENRY. *See* No. 1340.

522. MALLARD, ERNEST. Note sur un filon d'étain oxydé situé près du village de Montebras, commune de Soumans (Creuse).

Mem. Soc. Sci. nat. arch. Creuse, Vol. 3, 1862, Guéret, pp. 161-167.

Old excavations supposed to be ancient earthworks found to be over tin mines, to exploit which the work was done. Veins are in granite carrying black mica.

523. ———. Note sur les gisements stannifères du Limousin et de la Marche, et sur quelques anciennes fouilles qui paraissent s'y rattacher.

Ann. Mines, ser. 6, Vol. 10, 1866, Paris, pp. 321-352.

Extrait par l'auteur, C. R. Acad. Sci., Vol. 62, 1866, Paris, pp. 223-225.

Tin ores were discovered at Vaulry (Creuse) in 1812 and exploited by the government but given up in the '60's. Veins carried much columbite wolframite, mispickel, iron-arsenate, native copper, black oxide of copper, molybdenite, uranium-phosphate, fluorite, calcium phosphate, and barite.

FRANCE (Continued)

24. Mazade, —. Titan und Zirkonerde mit Molybdän, Zinn, Tungstein, Tantal, Cerium, Yttrium, Glycium, Nickel und Kobalt in den Mineral-Wassern von Neyrac. [Ardèche].
Institut, Vol. 20, 1852, Paris, p. 198.
Not available to the authors.

Pattison, S. R. *See* No. 1406.

Phillips, J. A., and Louis, H. *See* No. 1350.

25. Sénez, L. Des mines d'étain français. (Etr. de l'Union bretonne.)
1856, Nantes.
Not available to the authors.

26. Simonin, L. Sur les mines d'étain de la Villeder (Morbihan).
Bull. Soc. géol. France, ser. 2, Vol. 23, 1866, Paris, pp. 371-373.

Simonin, L. *See* No. 1416.

FRENCH GUIANA

27. Damour, A. Note sur la présence du platine et de l'étain métallique dans les terrains auriféres de la Guyane.
C. R. Acad. Sci., Vol. 52, 1861, Paris, pp. 688-690.
Reports metallic tin in a small specimen (2 grams) from the Approuague River, French Guiana.

GEORGIA

Rolker, Chas. M. *See* No. 1357.

U. S. Eleventh Census, 1890. *See* No. 1221.

GERMANY

28. Anonymous. Zinngewinnung zu Altenberg in sächsischen Erzgebirge.
Eisenzeitung, No. 24, 1888.
Treats of the occurrence, mining, ore dressing and smelting of tin of Altenberg.
Not available to the authors.

29. Beck, Richard. Einige Beobachtungen im Gebiete der Altenberg-Zinnwalder Zinnerzlagerstätten.
Zeitschr. prakt. Geol., 1896, Berlin, p. 148.

30. ———. Ueber die Erzlagerstätten von Schwartzenberg im sächsischen Erzgebirge.
Zeitschr. Deutsch. geol. Ges., Vol. 52, 1900, Protok., Berlin, pp. 58-60.
Digest: Trans. Inst. Mg. Eng., Vol. 22, 1901-1902 (1903), London and Newcastle-upon-Tyne, p. 700.
Near Schwarzenberg, in the Western Erzgebirge a dome of augen-gneiss forms the basement-rock which is mantled by mica-schist; on the north conformably overlain by phyllites but faulted against them on the south. All broken through by granite-dikes. In the altered schists occur two concentric ore belts intimately associated with crystalline limestone, dolomite and skarn (sahlite-actinolite-rock). Magnetite occurs in regular beds or inter-stratified with the limestone. Red and brown hematite beds are altered from magnetite. Other ores are in two dis-

GERMANY (Continued)

tinct groups: (1) pyrite-blende group, including iron-pyrite, zinc-blende, argentiferous galena and copper pyrite with some arsenical and magnetic pyrites, more rarely polybasite and native silver; (2) the stanniferous group, including tinstone in columnar crystals, molybdenite, specular-iron ore, etc.

The pyritic and stanniferous ores were the last constituents deposited from the siliceous solutions.

531. ———. Die Erzlagerstätten.

Erl. geol. Specialkarte Kön. Sachsen, 1903, Leipzig, pp. 40-57.

Digest: Trans. Inst. Mg. Eng., Vol. 27, 1905, London and Newcastle-upon-Tyne, p. 639.

The Graupen tin deposits are described.

———. *See* No. 1299.

532. BEUST, —, VON. Ueber die Zinnerzlagerstätten von Schlaggenwalde.

Berg. Hütt. Zeit., Vol. 27, 1868, Leipzig, pp. 3-4.

533. BLÖDE, GOTTLOB VON. Versuch einer Theorie über die Bildung des Geyer'schen Stockwerkes.

Tasch. ges. Min., Vol. 10, I, 1816, Frankfurt-am-Main, pp. 1-32.

Not available to the authors.

534. BONNARD, A. H. DE. Essai géognostique sur l'Erzgebirge ou sur les Montagnes métalliféres de la Saxe.

Journ. Mines, Vol. 38, 1815, Paris, pp. 261-318, 339-382, 415-452.

Also Tasch. ges. Min., Vol. 16, 1822, Frankfurt-am-Main, pp. 94-136, 508-538.

Treats of the Saxon tin mines.

535. BREITHAUPT, A. Die Paragenesis der Mineralien. Freiberg, 1849.

Said to treat of tin deposits of Germany.

Not available to the authors.

BROWN, A. SELWYN. *See* Nos. 1307 and 1308.

CHARLETON, ARTHUR G. *See* No. 1310.

536. CHARPENTIER, J. F. W. Mineralogische geographie der Thursachsischen Lande.

1778, Leipzig, geol. map, wood cuts 7.

Contains many references to the tin deposits at Altenberg and other places in Saxony.

537. COTTA, BERNARD VON. Das Altenberger Zinnstockwerk.

Berg. Hütt. Zeit., Vol. 19, 1860, Leipzig, pp. 1-2.

538. ———. Mineralien der Freiberger Erzgänge.

Berg. Hütt. Zeit., Vol. 19, 1860, Leipzig, pp. 301-305.

Gives a list of the tin and other minerals of the Freiberg ore deposits.

539. ———. Altenberg Zwittergestein Festschrift zum hundertjährigen Jubiläum der Königl. Sächs. Bergakademie zu Freiberg.

1866, Dresden, p. 156. (Not seen.)

Digest: Trans. Roy. Geol. Soc. Cornwall, Vol. 9, Penzance, p. 175.

"Prof. von Cotta proves that there is a gradual passage from fine grained reddish granite to the almost compact black stanniferous Zwittergestein. The Zwittergestein is an altered granite which has lost about 3 per cent of silica and 2 per cent of potash and has taken up 4 per cent of ferrous oxide, and ½ per cent of stannic oxide."—C. Le Neve Foster.

GERMANY (Continued)

10. ———. A treatise on ore deposits.
Trans. by F. Prime, 1870, New York.
Treats of Altenberg tin stockwerk, pp. 106-109; tin deposits of Zinnwald, pp. 109-110; tin deposits of Graupen and Poebel, pp. 111; tin deposits of Marienberg, pp. 114-115; tin deposits of Ehrenfriedersdorf and Geyer, p. 115; tin deposits of District of Johanngeorgenstadt and Eibenstock, pp. 123-124.

11. ———. Die Geologie der Gegenwart.
1872, Leipzig, pp. 154-159.
Describes the tin deposits of Germany, and more briefly the principal ones of other parts of the world.

D'ACHIARDI, ANTONIO. *See* No. 1313.

12. DALMER, KARL. Der Altenberg-Graupener Zinnerzlagerstättendistrict.
Zeitschr. prakt. Geol., 1894, Berlin, pp. 313-322, with text figs.
Digest: Trans. Fed. Inst. Mg. Eng., Vol. 10, 1895-1896, Newcastle-upon-Tyne and London, pp. 588-589.
In district north of Teplitz, Archæan rocks of the Erzgebirge are cut by quartz-porphyry, granite porphyry, and albite-granite intruded along fault lines. Tin closely connected with granite, which is youngest, but there are broad zones of impregnation around the granite, and these are the most important. Believes in pneumatolytic deposition. Seams contain chiefly quartz and lithia-mica with which are tinstone, wolframite and fluorspar, topaz being rarer. Chlorine shown to occur in the micas of Zinnwald, Graupen and Altenberg. Thinks chlorine played important part in the formation of the deposits. Stanniferous lodes near the "impregnation zones" contain galena, arsenical and copper pyrites and malachite. Tin lodes of Graupen district said to pass gradually southeastwardly into pyrite-veins. Believes blende-bearing lead ores to be also in causal connection with granitic intrusion, but that the conditions that originated them, acted further away than those of the tin veins.

13. DALMER, K. Gänge der Zinnerz- und kiesigblendigen Bleierzformation im Schneeberger Kobaltfelde.
Zeitschr. prakt. Geol., 1895, Berlin, pp. 228-229.

14. ———. Die Erzlager von Schwarzenberg im Erzgebirge.
Zeitschr. prakt. Geol., 1897, Berlin, pp. 265-272.

DAUBRÉE, A. *See* No. 1314.

DAGIES, D. C. *See* No. 1317.

15. DECHEN, H. VON. Die Bildung der Gänge.
Verh. nat. Ver. preuss. Rheinl. Westph., Vol. 7, 1850, Bonn., pp. 161-175.
Also, Neues Jahrb. Min., 1851, Stuttgart, pp. 210-220.
Tin deposits of Germany and England described.

FAWNS, SYDNEY. *See* No. 1320.

16. FREIESLEBEN, J. C. Das Kies-, Eisen- und Zinnsteinlager bei Breitenbrunn.
Geognostische Arbeiten, Vol. 5, pp. 47ff.
Extract: Tasch. ges. Min., 1820, Vol. 14, II, Frankfurt-am-Main, 1820, pp. 428-434.
Not available to the authors.

17. ———. Beiträge zur Geschichte, Statistik und Literatur des Sächsischen Erzbergbaues.
1848, Freiberg.
Not available to the authors.

GERMANY (Continued)

FUCHS, E., and LAUNAY, L. DE. *See* No. 1323.

GÄTZSCHMANN, M. F. *See* No. 1391.

548. GMELIN, J. F. Beyträge zur Geschichte des deutschen Bergbaues.
1783, Halle.
Not available to the authors.

549. GRODDECK, ALBERT. Traite des gites métallifères. Translated from the German by H. Kuss.
1884, Paris, pp. 242-251.
Describes tin stockworks at Altenberg, Geyer, and Zinnwald, Saxony; and tin veins at Schalaggenwald and Graupen, Bohemia. Brief references to tin deposits are made at a number of other places in the book.

550. HALLWICH, H. Das Zinnerz-Vorkommen zu Graupen und Obergraupen und Art und Weise des Bergbaues daselbst in alter und neuer Zeit.
Oest. Zeitschr. Berg. Hütt., Vol. 16, 1868, Wien, pp. 150-151, first article.
Extract from Dr. Hallwich's "Geschichte der Bergstadt Graupen."

JARS, G. *See* No. 416.

551. KLIPSTEIN, A. Altenberger Zinnstocks.
Neues Jahrb. Min., Vol. 1, 1830, Stuttgart, pp. 256-261.

LAMPADIUS, W. A. *See* No. 1516.

551a. LEPSIUS, RICHARD. Geologie von Deutschland und den angrenzenden gebieten.
Vol. 1, 1903, Leipzig, p. 66 et seq.
The tin deposits of the Erzgebirge are briefly treated.

LOUIS, HENRY. *See* No. 1340.

552. MANÈS [—]. Mémoire sur les mines d'étain de Saxe.
Ann. Mines, Vol. 8, 1823, Paris, pp. 499-594, 837-886; Vol. 9, 1824, pp. 281-304, 463-476, 625-656.
Not available to the authors.

553. MANN, O. Zur Kenntniss erzgebirgischer Zinnerzlagerstätten.
Sitz. Abh. Nat. Ges. "Isis," 1904, Dresden, pp. 61-73, figs. 2, geol. map.

554. MIKLUCHO-MACLAY, M. VON. Rutil und Zinnstein im Greifenstei[illegible] Granit. (Ehrenfriedersdorf.)
Neues Jahrb. Min., 1885, II, Stuttgart, pp. 88-90.
Occurrence of cassiterite as original rock making constituent: with rutile lithia mica of "Greifenstein."

555. MÜLLER, HERMANN. Ueber die Bildung der Zinnstockwerke im östlic[illegible] Erzgebirge.
Berg. Hütt. Zeit., Vol. 24, 1865, Leipzig, pp. 178-180.
Neues Jahrb. Min., 1865, Stuttgart, pp. 866-868.

556. ———. Beiträgen zur geognostischen Kenntniss des Erzgebirges.
Vol. 2, 1867, Freiberg,
Extract; Neues Jahrb. Min., 1867, Stuttgart, pp. 616-619.
Not available to the authors.

GERMANY (Continued)

57. ———. Ueber die Erzlagerstätten in der Umgegend von Berggiesshübel.
Erl. geol. Specialkarte Kön. Sachsen, 1890, Leipzig, p. 55.
Gänge der Zinnerzformation.

58. ———. Die Erzgänge des Annaberger Bergrevieres.
Erl. geol. Specialkarte Kön. Sachsen, 1894, Leipzig. Zinnbergbau in den Annaberger Revieren, pp. 32-36. Gänge der Zinnerz-Formation, pp. 67-71.

59. ———. Die Erzgänge des Freiberger Bergrevieres.
Erl. geol. Specialkarte Kön. Sachsen, 1901, Leipzig, pp. 129-141.
Treated under heads: Zinnerz und Kupfererz führende Gänge; Zinnstockwerk bei Seiffen; Zinnseifenablagerungen bei Seiffen; Zinnerz führende bei Freiberg; Zinnseifen in der Gegend von Freiberg und Dorfhain.

60. Müller, H., und Richter [—]. Ueber das Vorkommen von Zinn in der Zinkblende der Freiberger Erzgänge.
Berg. Hütt. Zeit., 1851, Leipzig, pp. 353-356.

Nowicki, Constantin von. *See* No. 71.

61. Oppe, H. V. Die Zinn- und Eisenerz-Gänge der Eibenstocker Granitpartie und deren Umgebung inner halb der Bergamtsreviere Johanngeorgenstadt und Schneeberg.
In Cotta (B.) Gang-studien, Vol. 2, Freiberg, 1854, pp. 133-195.
Digest: Neues Jahrb. Min., 1853, Stuttgart, pp. 725-726.

Phillips, J. A., and Louis, H. *See* No. 1350.

Rammelsberg, C. *See* No. 1637.

62. Reuss, A. E. Die Umgebungen von Teplitz und Bilin, in Beziehung auf ihre geognostischen Verhältnisse. Prag und Teplitz, 1840.
Der Zinngänge bei Graupen, p. 4; ueber das Zinnwalder Stockwerk und die Zinngänge im Seegrunde, pp. 40-51.

63. Reyer, Eduard. Ueber die erzführenden Tieferuptionen von Zinnwald-Altenberg und über den Zinnbergbau in diesem Gebiete.
Jahrb. k. k. geol. Reichs., Vol. 29, 1879, Wien, pp. 1-60, figs. 4.
Digest: Oest. Zeitschr. Berg. Hütt., Vol. 27, 1879, Wein, pp. 494-495.

64. ———. Tektonik der granitergüsse von Neudeck und Karlsbad, und Geschichte des Zinnbergbaues im Erzgebirge.
Jahrb. k. k. geol. Reichs., Vol. 29, pt. 3, 1879, Wien, pp. 405-461.
"This memoir is divided into:
1. A study of the relations of the granite and schists.
2. A discrimination of the various local kinds of granite, as being necessary for a knowledge of the nature and origin of the granite masses; with both earlier descriptions of the several granites and the author's own researches.
3. The history of the most important tin-bearing rocks and tin works of the districts. These chapters are illustrated with several wood cuts, among which is a plan of the country between Carlsbad, Ebenstock and Schwarzenberg."

GERMANY (Continued)

573a. SINGEWALD, J. T., JR. The Erzgebirge tin deposits.

Econ. Geol., Vol. 5, 1910, Lancaster, pp. 166-177, 265-272, figs. 2. (geol. maps) and 1 plate.

The tin deposits are grouped around two belts of granite cutting across the Erzgebirge, between Saxony and Bohemia. Around the eastern belt are the tin mines of Sadisberg, Altenberg, Zinnwald, and Graupen, and around the western are those of Schneeberg, Annaberg, Joachimstahl, etc.

At Sadisdorf a stockwork of veinlets has made zwitter of the granite—the feldspars having been replaced by topaz and quartz. Cassiterite, fluorspar, pyrite, arsenopyrite, chalcopyrite, chalcocite and cuprite have been impregnated in the granite. An eighteen-foot quartz vein carrying fluorspar, wolframite, molybdenite, and zinnwaldite cuts the granite. At Altenberg is a similar zwitter which extends downward about 700 feet. It carries an average of about 0.3 per cent tin and 0.002 per cent of bismuth. At Zinnwald quartz veins 1½ to 2 feet thick carrying cassiterite and wolframite (which is more important), with zinnwaldite, are worked. At Graupen the Luxer vein, now worked, contains white quartz which in places gives way to coarsely crystalline orthoclase and albite and to fluorspar. Cassiterite, lithium mica, wolframite, chalcopyrite, and galena are the other vein minerals.

At Geyer zwitter bands are mined. At the Leier Mine north of Geyer a greisen dike 3 feet wide, locally carrying 1 per cent tin, and tin-bearing veins are worked. The ores carry nearly 30 per cent of iron and arsenic. At Sauberg, tin veins occur in gneissic mica schist. No granite has been encountered. There are five groups which consist of 3 to 15 parallel veins each, 1 to 3 feet apart, and from 2 to 10 inches wide. They carry much arsenopyrite and some wolframite. At one place they are faulted by a silver cobalt vein.

The deposits on the Austrian side are not described.

574. STELZNER, A. W. Beiträge zur geognostischen Kenntniss des Erzgebirges.

Vol. 1, 1865, Freiberg, pp. 3-58.

Abstract: Die Granite von Geyer und Ehrenfriedersdorf sowie die Zinnerzlagerstätten von Geyer.

Neues Jahrb. Min., 1865, pp. 863-866; 1866, Stuttgart, pp. 229-230.

575. ———. Beiträge zur Entstehung der Freiberger Bleierz- und der erzgebirgischen Zinnerzgänge.

Zeitschr. prakt. Geol., 1896, Berlin, pp. 377-412.

Digest: Neues Jahrb. Min., 1898, II (Min), Stuttgart, pp. 72-74.

Thinks ore deposits due to ascending waters. No rutile present in deposits.

STELZNER, A. W., and SCHERTEL, A. *See* No. 1643.

576. STERNBERGER, KARL. Die ärarischen Bergbau-Unternehmungen im böhmischen Erzgebirge.

Oest. Zeitschr. Berg. Hütt., Vol. 5, 1857, Wien, pp. 62-63.

577. TELKIN (Vice-Consul). Tin mining in Saxony.

Mg. Journ. Railw. Comm. Gaz., Vol. 81, 1907, London, p. 624.

Notes a revival of Erzgebirge mines, which flourished in 16th and 17th centuries, "but began to be abandoned when the South American deposits were discovered."

578. VIERIG, W. Die Silber-Wismutgänge von Johanngeorgenstadt im Erzgebirge.

Zeitschr. prakt. Geol., Vol. 13, 1905, Berlin, pp. 95-96.

578a. WEINSCHENK, ERNST. Die Kieslagerstätte im Silberberg bei Bodenmais.

Abh. Math. Phys. Classe Kön. Bay. Akad. Wiss., Vol. 21, München, 1901, pp. 349-410.

GERMANY (Continued)

Digest Translation: Trans. Inst. Mg. Eng., Vol. 22, 1901-2 (1903), London and Newcastle-upon-Tyne, p. 694.

"Among other interesting minerals from this locality are graphite, tinstone, tourmaline, garnet, etc."

GREENLAND

579. ALLEN, THO. Memorandums respecting some minerals from Greenland.

Ann. Philos., 1813, London, p. 107.

Tin is briefly mentioned as being found among other minerals in Greenland.

580. ANONYMOUS. Half hours in the far north.

Dodd, Mead and Co., New York, p. 145.

"We were happy enough to obtain a few minerals, some specimens of rough garnets, allanite, tantalite, molybdenite, etc., with copper, tin, and iron ores in small quantities (near Frederikshaabs, Greenland)."

581. BOGGILD, O. B. Mineralogia Groenlandica.

Medd. Grönl., Vol. 32, 1905, Kjøbenhavn, pp. 89-91.

Mentions the finding of cassiterite in Greenland.

582. FLINK, GUST. Berättelse om en mineralogisk resa i Syd-Grönland sommaren 1897.

Medd. Grönl. 14de hefte, 1898, Kjøbenhavn, p. 261.

(Résumé des Communications sur le Grönland p. 416.)

Briefly mentions cassiterite as having been found in small quantities during the trip.

583. GIESECKE, K. L. Mineralogiske rejse i Grönland.

1878, Kjøbenhavn.

Cassiterite was found in the Christianshaabs district (p. 83); in the Frederikshaabs district on Arsuk Fjord (pp. 161, 180 and 338) and at Itivdliarsuk in the Godhavn district (p. 289).

Unimportant except as showing distribution and mineralogical occurrence.

584. HOFF, TH. Om tinstenens forekomst ved Ivikaet ved Arsut Fjord i Syd-Grönland.

Vid. Medd. nat. Foren. Kjøbenhavn, for 1854 (1855), Kjøbenhavn, pp. 201-204, fig. 1 in text.

585. RINK, HENRY. Danish Greenland its people and its products. Edited by R. Brown.

1877, London, p. 391.

Merely states that "tinstone accompanies the cryolite."

586. TAYLER, J. W. On the veins of tin-ore at Evigtok, near Arksut, Greenland.

Quart. Journ. Geol. Soc. London, Vol. 15, 1859, London, pp. 606-607.

Quoted in Fawns, Sydney, "Tin deposits of the world," 1905, p. 146.

About twenty veins through an area 80 by 1500 feet, also disseminated through rocks with fine grained galena and tantalite. One and one-half inches of cassiterite on one side of largest vein, which is ten inches wide. Gangue feldspar, quartz, fluorspar, and "sparry iron"; vein runs into white cryolite. Other accompanying minerals are "blende," copper, iron and arsenical pyrites, black cryolite, "molybdena," and zircon. No wolframite.

HONDURAS

MONTIS, E. DE. Mining in Honduras.

Mex. Mg. Journ., Vol. 7, 1908, Mexico, p. 24.

Makes bare statement that, among other metals, tin is found in Honduras.

IDAHO

HANKS, H. G. *See* No. 218.

LINDGREN, WALDEMAR. A geological reconnaissance across the Bitterroot Range and Clearwater Mountains in Montana and Idaho.

U. S. Geol. Surv., Prof. Paper No. 27, 1904, Washington, D. C., p. 89.

"Stream tin [wood tin, F. L. H.] is frequently found with the gold in this [Hughes] creek."

INDIA

ANONYMOUS. Occurrence of tin in India.

Mg. Journ. Railw. Comm. Gaz., Vol. 75, 1904, London, p. 605.

Note stating a new discovery of tin ore has been made at Hosainpura, State of Palanpur. Mineral occurs in large distinct crystals, together with the mineral gadolinite, as a constituent of tourmaline-pegmatite.

———. Mineral production of India.

Bull. Imp. Inst. Great Britain, Vol. 4, No. 2, 1906, London, pp. 156-164.

Brief review of mineral productions of India as given by Rec. Geol. Surv. India, Vol. 33, pt. 1, 1906, Calcutta, pp. 1-32.

"Tin ore is found in the Hazáribágh district of Chota Nagpur and other localities of India proper, but it has only been worked to any extent in South Burma. The total output in 1904 just exceeded 70 tons. It is sent to the Straits Settlements, from which the greater part of the tin imported into India is obtained. The metal is mainly employed in India to form a coating in the inside of copper cooking utensils, which is renewed from time to time. The consumption shows no signs of increase." (Whole Ref.)

BALL, V. A manual of the geology of India.

Geol. Surv. India, pt. 3, 1881, Calcutta, pp. 313-322.

The only localities (Indian) where tin ore occurs in sufficient quantities to be of commercial value are situated in the Tenasserim division of British Burma.

———. The mineral resources of India and their development.

Journ. Soc. Arts, Vol. 30, 1882, London, p. 583.

Although ores of tin do occur in parts of the Indian Peninsula, there is at present time no deposit large enough to warrant working to any great extent. Localities where tin ore occurs are numerous. Mostly included in the strip of land in Tenasserim which extends from Yé to Maleewoon, a distance of about 400 miles. Sources of stream tin, which is found in the majority of rivers of this district, are in range of hills separating British Tenasserim from Siam. An attempt was made by a British company at Maleewoon to work deposits, but it resulted in loss. Working of ore is carried on by Chinese, Shans and Burmese.

D'ACHIARDI, ANTONIO. *See* No. 1313.

HOLLAND, T. H. Tin ore and gadolinite in Palanpur.

Rec. Geol. Surv. India, Vol. 31, 1904, Calcutta, p. 43.

In Sept. 1903, tin ore was discovered at Hosainpura, Palanpur State. "Mineral occurs in distinct, large crystals as a constituent of tourmaline-pegmatite together with the mineral gadolinite."

INDIA (Continued)

592. KING, W. Index of the local distribution of important minerals, etc., in India.

Rec. Geol. Surv. India, Vol. 22, pt. 4, 1889, Calcutta, p. 254.

Tin ores are mentioned as coming from Chota Nagpur; Nurgo or Nurunga, where there are grains of tinstone in gneiss; Phira, and at Simratari, where mere traces have been found.

593. MALLET, F. R. Geological notes on part of Northern Hazáribágh.

Rec. Geol. Surv. India, Vol. 7, pt. I, 1874, Calcutta, pp. 35-36, 43.

Cassiterite, is found at Nurgo, a village south of Baraka in grains thickly distributed through a thinly foliated gneiss containing some thin "seams of pegmatite." Also occurs in lepidolite in pegmatite at Pihra, and in granite cutting mica schist at Simratari, west of Pihra.

Natives smelted tin ore for iron ore and when they saw the white metal, thought they had obtained silver.

594. ———. A manual of the geology of India. pt. 4.

1887, Calcutta, pp. 54-55.

"Tinstone has been reported from several parts of the peninsula of India, but nowhere has it as yet been found in any quantity."

595. MEDLICOTT, H. B. and BLANFORD, W. T. Tin in India.

Manual of the Geology of India, Calcutta, 1879, pp. 19, 708.

Mr. Mallet found tinstone in the gneiss in district of Hazáribágh. Tinstone is found in some abundance in parts of the Tenasserim and in Martaban.

596. OATES, ROBERT. The copper and tin deposits of Chotâ-Nagpore, Bengal, India.

Trans. Fed. Inst. Mg. Eng., Vol. 9, 1895, Newcastle-upon-Tyne and London, pp. 445-451, pls. 24, 25.

Gives geology, account of the working, machinery used and results obtained, at Narungo tin-mine, 5 miles north of Baragunda.

PHILLIPS, J. A., and LOUIS, H. *See* No. 1350.

597. RUDRA, SARAT C. Mineral resources of British India.

Trans. Amer. Inst. Mg. Eng., Vol. 34, 1904, New York, p. 828.

"Although no deposit of tin ore has yet been discovered in Peninsular India, stray samples have been found in Bengal, Chotâ-Nagpur, Bombay and Bastar. The only place in British India where this mineral is known to exist in a large quantity is in Lower Burma, at Amherst, Tavoy and Mergui."

598. STEPHENS, F. J. Geology and mineral resources of Kumaon and Garhval.

Trans. Inst. Mg. Met., Vol. 10, 1901-1902 London, pp. 394, 401, 411.

Tin is briefly mentioned as occurring in small quantities in India.

IRELAND

599. ANONYMOUS. Tin ore and gold in Wicklow, Ireland.

Amer. Journ. Sci. Arts, ser. 2, Vol. 11, 1851; New Haven, p. 233.

Gives following analysis of tin ore made by W. Mallet:

"Peroxyde of tin	95.26
Peroxyde of iron	2.41
Silica	0.84
	98.51"

FAWNS, SYDNEY. *See* No. 1320.

IRELAND (Continued)

FITTON, WILLIAM. Notice respecting the geological structure of the vicinity of Dublin; with an account of some rare minerals found in Ireland.

Trans. Geol. Soc. London, Vol. 1, 1811, London, p. 270.

Tinstone found in the gold mines of Wicklow.

KINAHAN, G. H. On the mode of occurrence and the winning of gold in Ireland.

Sci. Proc. Roy. Dublin Soc., n. s., Vol. 3, 1883, Dublin, p. 272.

Tinstone crystals are mentioned as occurring with the gold at Ballinvally. Found also in Monaglogh and Coolbawn.

———. Economic geology of Ireland.

Journ. Roy. Geol. Soc. Ireland, Vol. 18 (Vol. 8, new series), 1889, Dublin, pp. 11, 17, 79, 82, 86, 121, 122.

A collection of papers appearing in the Sci. Proc. Roy. Dublin Soc., from March 1886 onward. Three counties in which tin is said to be found:

1. County Dublin, Dalkey, at Kingstown with lead and zinc in granite. Only place in Ireland that it is known in a lode. Rumored at Kilcrohane (Sheep Head) County Cork, but not authenticated.

2. County Kerry, Lough Leane, Killarney. Questionably.

3. County Wicklow, Goldmine River, Woodenbridge, in gravels with gold and magnetic sand. Suggests possibility of finding tin lodes at last place.

———. Notes on mining in Ireland.

Trans. Inst. Mg. Eng., Vol. 26, 1903, London and Newcastle-upon-Tyne, pp. 279-280, 286.

Tin ore in the Ovoca district, County Wicklow, has not been found in place. Thinks it may occur in copper-bearing veins in the district and that copper may give way to tin in depth. Treats shortly of old bronze, showing that tin was known in Ireland long ago.

Only localities where tin is known are Dalkey, County Dublin, and the Goldmine Valley, County Wicklow. Said to have been found near the lakes of Killarney, County Kerry.

H. J. Seymour is quoted as crediting minute crystals of cassiterite to the Mourne Mountains.

MACLAREN, J. MALCOLM. The occurrence of gold in Great Britain and Ireland.

Trans. Inst. Mg. Eng. Vol. 25, 1902-1903, Newcastle-upon-Tyne and London, p. 494.

States that in the Croghan Kinshelagh area, County Wicklow, Ireland, "the black sand is composed mainly of magnetite, ilmenite, hematite and iron pyrite, but cassiterite, galena, wolframite, molybdenite, gold, copper-pyrite and oxides of manganese also occur in the sand. The late Mr. W. Mallet records having obtained from a washing of 150 pounds, no less than 3½ pounds of stream tin, in all sizes from small grains up to pebbles ½ inch in diameter and of the variety known as wood-tin."

MALLET, W. On the minerals of the auriferous district of Wicklow.

Journ. Geol. Soc. Dublin, Vol. 4, 1848, Dublin, pp. 272-273.

Abstract: London, Edinburgh, Dublin Philos. Mag. Journ. Sci., Vol. 37, 1850, London, pp. 393-394.

Brief abstract: Amer. Journ. Sci. Arts, 2d ser. Vol. 11, 1851, New Haven, p. 282.

Tin in County Wicklow, Ireland, "Should this mineral be found in the mass of sand in a quantity at all approaching that in which it existed in the specimen examined, it would probably richly repay the labor and expense of collection and smelting. The fact of the existence of tinstone in such considerable quantity in these auriferous streams, would seem to indicate the probable existence somewhere in the surrounding district of masses of ore, and possibly forming the continuation of those vast deposits of Cornwall."

IRELAND (Continued)

606. SEYMOUR, H. J. On the occurrence of cassiterite in the tertiary granite of the Mourne Mts., County Down.

Sci. Proc. Roy. Dublin, Soc., Vol. 9, 1902, Dublin, p. 583, 584.

This occurrence of cassiterite in an undoubted Tertiary granite is of great interest, as tending to show the comparatively recent origin of some mineral lodes. First record of the occurrence of tin in Ireland dates from 1796.

607. SMITH, AQUILA. On Irish tin ore.

London, Edinburgh, Dublin Philos. Mag. Journ. Sci., ser. 3, Vol. 18, 1841, London, pp. 134-136.

Tin ore is said to have been found in Wicklow County about 1796, in some gold mines. Messrs. Mills, King and Weaver, published in Trans. Dublin Soc., Vol. 2, 1801, Dublin, p. 147, an announcement of the occurrence of tinstone crystals associated with the gold in Croghan Mts. in Wicklow County. This is first announcement of the existence of tin in Ireland. The author in examining some washed sand from the gold works in Wicklow County, found small particles of "native tin oxide."

608. WEAVER, THOMAS. Memoir on the geological relations of the east of Ireland.

Trans. Geol. Soc. London, Vol. 5, 1821, London, p. 135.

Mentions "tinstone" as having been found in granite, and stream tin at Croghan Kinshela, County Wicklow.

609. ———. On Irish tin ore.

London, Edinburgh, Dublin Philos. Mag. Journ. Sci., ser. 3, Vol. 19, 1841, London, pp. 27-31.

Mr. Weaver reviews the paper on Irish tin ore by Aquila Smith, printed in Philos. Mag., Vol. 18, 1841, London, pp. 134-136. Mentions that tin, contrary to Mr. Smith's assertion, is found in three distinct localities in Ireland, two in the county of Wicklow, and one in county of Dublin.

ITALY

610. ANONYMOUS. A tin mine in Tuscany.

Journ. Appl. Sci., Vol. 7, 1876, London, p. 56.

Notes the discovery of a vein of cassiterite near Campiglia, Tuscany. The vein is about 4 inches wide, between limonite and a Lias limestone. Believed to be the first time tin has been found unconnected with granite.

611. ———. The discovery of tin ore in Italy and its relation to the bronze manufacture of the ancients.

Iron, Vol. 14, 1879, London, pp. 166-167, 322-324.

612. BECO, JEAN, and THONARD, LÉON. L'industrie minérale en Italie depuis 1860 jusqu'en 1880.

Rev. Univ. Mines Mét. Trav. Publ. Sci. Arts Appl. Indust. ser. 2, Vol. 14, 1883, Paris and Liége, p. 115.

The oxide of tin was discovered in Tuscany in 1876.

613. BERGEAT, ALFRED. Beiträge zur Kenntniss der Erzlagerstätten von Campiglia Marittima (Toscana) insbesondere des Zinnsteinvorkommen dortselbst.

Neues Jahrb. Min., Vol. 1, 1901, Stuttgart, pp. 135-156, text figs. 2, pl. 7.

Review: Zeitschr. prakt. Geol. 1901, Berlin, pp. 422-423.

Digest: Trans. Inst. Mg. Eng., Vol. 22, 1901-1902, London and Newcastle-upon-Tyne, pp. 705-706.

ITALY (Continued)

These stanniferous deposits differ from all others known, for they do not appear to be associated with eruptives, but occur in limestone with hematite. Campiglia is 12½ miles from Massa Marittima, 18 miles from Elba and about same distance from borax-producing localities of Larderello and Castelnuovo. Ore deposits extend in belt of over 3 miles from Monte Valerio to Monte Calvi. 1¼ miles southwest of town are tin ores, 2 miles northwest are sulphide-ores—argentiferous-galena, pale and dark zinc blende, pyrite and chalcopyrite. Ores intimately associated with cordierite-bearing quartz trachyte, epidote, chlorite, ilvaite, manganiferous pyroxene, quartz, and fluorspar, separated from tin-deposits by Marmi valley. These ores are eruptive and metasomatic. No tin in them. Tin deposits are on Monte Valerio and Monte Fumacchio. Country-rock gray or pinkish marble, probably Middle Lias, overlain by variegated Upper Lias slates, with quartz nodules. No eruptives to be seen here. Tin ore in limonite in fissures in slates and very irregular metasomatic masses in limestone. Thinks ores are not of secondary concentration and are not a stanniferous gossan. Gangue is calcite and kaolin. None of ordinary accompanying minerals of tin. Copper ores of Boceheggiano and Massa Marittima are stanniferous.

4. BLANCHARD, FRÉD. Sur la découverte de la cassitérite à Campiglia Marittima.
Atti R. Accad. Lincei (Mem.), ser. 2, Vol. 3, 1875-1876 (1876), Roma, pp. 93-94.

5. ———. Sulla scoperta della cassitérite à Campiglia Marittima.
Bol. R. Com. geol. Italia, Vol. 7, 1876, Rome, pp. 52-54.
Digest: Geol. Rec. for 1876, London, p. 194.
At Cento Camerelle, on west side of Monte Fumacchio, a small tin-vein occurs, accompanied by limonite. Has east-westerly direction, with underlay to south. Country rock is Lower Lias limestone.

6. ———. Sulla miniere di stagno in Campiglia.
Atti R. Accad. Lincei (Trans.), ser. 3, Vol. 2, 1877-1878 (1878), Rome, pp. 186-191.

7. BRAUN, MAX. Zinnstein in Italien.
Neues Jahrb. Min., 1877, Stuttgart, pp. 498-499.
A communication describing Italian tin deposits.

BROWN, A. SELWYN. *See* Nos. 1307 and 1308.

8. CAILLAUX, ALF. Note sur la découverte de minerai d'étain en Toscane.
Bull. Soc. Geol. France, ser. 3, Vol. 4, 1875-1876 (1876), Paris, pp. 293-295.
Geologically, an important discovery on account of its rather unusual occurrence. Two analyses were made of this tin by Hallway of London:

Oxyde d'étain	75.18	92.40
—— de fer	4.00	3.49
Carbonate de chaux	19.64	3.34
Plomb et bismuth	traces	0.00
Matières indéterminées	1.18	0.77
Total	100.00	100.00
Étain métallique	58.90	72.00

9. CHARLON, E. Note sur la découverte de l'étain oxydé en Toscane.
Ann. Mines, ser. 7, Vol. 9, 1876, Paris, pp. 119-122.

10. CHURCH, A. H. La scoperta del minerale di stagno in Italia, e sua relazione colla lavorazione del bronze presso gli antichi.
Bol. R. Com. geol. Italia, Vol. 10, 1879, Rome, pp. 382-394, 545-556.

ITALY (Continued)

621. D'Achiardi, Antonio. Entdeckung des Zinnsteins in Campiglia Marittima.

Neues Jahrb. Min., 1876, Stuttgart, p. 285.
Digest: Geol. Rec. for 1876, London, p. 222.
"Notes on the discovery of cassiterite, with brown iron ore, in the Cento Camerelle, where the Romans and perhaps the Etruscans, had important mines. The tinstone contains 72.45 per cent tin."

———. *See* No. 1313.

622. Dalmer, Karl. Zinnerzlagerstätten.

Zeitschr. prakt. Geol. 1894, Berlin, p. 400.
Additions made to a communication by Herr Gurlt concerning the occurrence of tin in Campiglia.

623. Ernst, C. von. Die Montanindustrie Italiens.

Oest. Zeitschr. Berg. Hütt., Vol. 31, 1883, Wien, p. 507.
Brief account of localities, and manner of occurrence of tin in Italy, also production from 1876 to 1880 inclusive.

Fawns, Sydney. *See* No. 1320.

Fuchs, E., and Launay, L. de. *See* No. 1323.

624. Gurlt, A. Zinn-Vorkommen im Kalkstein von Cava del Fumacchio bei Campiglia, Toscana.

Zeitschr. prakt. Geol. 1894, Berlin, pp. 324-326.
Remarks on this article by Karl Dalmer, p. 400.

625. Herter, Paul, and Rath, G. von. Zinnstein von Campiglia.

Zeitschr. deutsch. geol. Ges., Vol. 29, 1877, Berlin, pp. 194-196.

626. Langer, J. H. Zinnsteinvorkommen in Toscana.

Oest. Zeitschr. Berg. Hütt., Vol. 24, 1876, Wien, p. 502.

627. Lotti, B. Sulla genesi dei giacimenti metalliferi di Campiglia Marittimi in Toscana.

Bol. R. Com. geol. Italia, Vol. 31, 1900, Rome, pp. 327-337, sections 2.
Digest Trans.: Trans. Inst. Mg. Eng., Vol. 22, 1901-1902, London and Newcastle-upon-Tyne, pp. 704-745.
Quartz-trachytes, some of them bearing tourmaline, and tourmaline-granite cut gray and white limestones of lower Liassic. Metalliferous deposits in more direct contact with trachyte than with granite. At Campo Alle Buche at the contact of the granite and gray limestone are masses of hematite, limonite, carbonate of lead and traces of cassiterite. At Monte Valerio are notable deposits of tin with the iron ore in the white Lower Lias limestone. At the Cento Camerelle tin and iron ores occur in the red Middle Lias limestone and continue into Lower Lias. Are in a horizontal vein with tin ore in lower part of ore-body. Trachyte changes to pyroxenite with epidote and garnet in contact with limestone country-rock. Ore deposits same age as intrusives, post-Eocene, not later than upper Miocene. The sulphides are probably the outcome of infiltration of siliceous metalliferous solutions, possibly (after Vogt and De Launay) from magmatic segregation. Iron and cassiterite come from oxidation of sulphides. Cassiterite probably carried from granite by alkaline carbonate solution with carbonate of iron which was later decomposed into oxide.

628. Phillips, J. A., and Louis, Henry. A treatise on ore deposits.

1896, London, pp. 476-477.
In Italy tin was found in connection with hematite, near Campiglia Marittima, in 1875. In Lower Lias limestone in fissures in connection with hematite. 70 tonnes of ore produced up to 1894, but none during that year.

JAPAN

NONYMOUS. Les Mines du Japon.

Bureau des Mines, 1900, Paris, pp. 294-297.

Tin occurs in tertiary tuffs, with galena and pyrite at Taniyama. Ore said to carry 10 per cent of tin.

——. Outlines of the geology of Japan.

Imp. Geol. Surv. Japan, 1902, Tokyo, pp. 183-184.

Kiura mine, situated in Bungo province was discovered many hundred years ago, and was once prosperous. At present ore is almost exhausted. Tin ore occurs in cavities in limestone. Taniyama mine was discovered in 1655, was most productive between 1848-1860, annually yielding from 120,000 to 130,000 kin of tin. Ore occurs in veins. Stream tin is found in vicinity of Takayama and Hirukawa.

——. *See* No. 1672.

CK, RICHARD. *See* No. 1299.

ACHIARDI, ANTONIO. *See* No. 1313.

AWNS, SYDNEY. *See* No. 1320.

DFREY, J. G. H. On the geology of Japan.

Quart. Journ. Geol. Soc. London, Vol. 34, 1878, London, pp. 542-555, 100 words.

Tin ore occurs only in small quantities. Found in province of Bungo and Satsuma (Taniyama). Estimate of total production per annum is 7½ tons.

MBO, KOTORA. Notes on the minerals of Japan.

Journ. College Sci. Imp. Univ. Tokyo, Vol. 11, 1899, Tokyo, pp. 224, 231.

Describes specimens of cassiterite from Mino, Satsuma, Bungo and Hitachi provinces. Brief.

UNROE, HENRY S. The mineral wealth of Japan.

Trans. Amer. Inst. Mg. Eng., Vol. 5, 1877, Easton, Pa., pp. 297-299.

Reprint: Eng. Mg. Journ., Vol. 22, 1876, New York, p. 427.

Translated from the English by Leon Thonard, in Rev Univ. Mines, Mét. Trav. Publ. Sci. Arts Appl. Indust., ser. 2, Vol. 2, 1877, Paris and Liége, pp. 273-275.

Tin is found in but three of the thirty-five ken of Japan, so far as author knows, only in veins. Nearly all tin produced comes from Taniyama mine. There are, here, 21 distinct veins of tin averaging 1½ feet in in thickness, but varying from a few inches to four feet. The ore is cassiterite, found in almost microscopic crystals scattered through a gangue of quartz. Method of treating the ore is given.

IN, J. J. The industries of Japan.

English translation, 1889, London, p. 303.

Merely a note. Little tin in Japan; on island of Kinshin and Tani-yama in Satsuma; and in Ohira-tetsu-san, in Bungo. These localities are in the southern end of Japan.

LKER, CHAS. M. *See* No. 1357.

ADA, TSUNASHIRO. The mining industry of Japan during years 1867-1892.

Mining Bureau Dept. Agriculture and Commerce, 1893, Tokyo, pp. 1, 300.

Tin has been mined since the end of the 7th century. Production in 1890, from Taniyama, 791 piculs.

JAPAN (Continued)

636. ———. **Minerals of Japan.**

Translated by T. Ogawa, 1904, Tokyo, pp. 50-51.

Cassiterite sometimes occurs in fluviatile deposits, as in the provinces of Mino and Bungo, and sometimes in rocks as in the provinces of Satsuma, Hitachi, Suo and Hyūga. It occurs usually in small quantities, and the mineral is worked only in Satsuma and Hyūga.

KAMERUN

637. ANONYMOUS. **Tin deposits in Kamerun.**

Mg. Journ. Railw. Comm. Gaz., Vol. 76, 1904, London, p. 405, 150 words.

Digest from Mg. Mag., Vol. 10, 1904, New York, p. 336.

"Brief confirmation of the truth of important discoveries of pure tin in British, French and German possessions in Northern Nigeria."

638. ———. **Kamerun tin deposit.**

Zeitschr. prakt. Geol., Vol. 12, 1904, Berlin, pp. 427-428.

Paragraph stating that tin has been found in Kamerun along the British Nigerian boundary, and that two companies had acquired mining rights.

639. MACCO, A. **Die nutzbaren Bodenschätze der deutschen Schutzgebiete.**

Zeitschr. prakt. Geol., Vol. 11, 1903, Berlin, pp. 28-33, 193-202, map.

Digest: Trans Inst. Mg. Eng., Vol. 24, 1902-1903 [1904], London and Newcastle-upon-Tyne, p. 712.

"Tin ore certainly occurs in that area [Kameroons] but how and where the natives work it is as yet unknown."

FAWNS, SYDNEY. *See* No. 1320.

KOREA

640. OPPERT, ERNEST. **A forbidden land: Voyages to the Corea.**

1880, London, pp. 171-172.

Briefly mentions that quicksilver, lead and tin are found in province of Hoang-hai.

LAOS

641. ANONYMOUS. **L'étain au Laos.**

Métallurgie, Vol. 32, 1901, Paris, pp. 891, 893.

642. ———. **L'étain au Laos.**

La Nature, Vol. 32, I, Dec. 26, 1903 (1904), Paris, pp. 58-59.

Short general article giving the location, general geology and mineral associations, of the tin deposits of Laos, and the manner of working.

643. GASCUEL, L. **Gisements stannifères au Laos Français.**

Ann. Mines, ser. 10, Vol. 8, 1905, mem., Paris, pp. 321-332, fig., sketch map.

Digest: Geol. Centr. Vol. 7, 1905-1906, Leipzig, p. 683.

La vallée du Nam-Patène montre un synclinal de grès argileux, flanqué de part et d'autre par des calcaires. Les grès paraissent d'âge tertiaire. Ces grès renferment d'importants dépôts de limonite, parfois très manganésifère; l'oxyde d'étain y est en outre répandu à l'état de fine division.—L. Pervinquière.

644. LACROIX, ALFRED. **Sur les gisements stannifères de Hin-boun (Laos).**

Bull. Soc. franc. Min., Vol. 24, 1901, Paris, pp. 422-425.

Digest Translation: Trans. Inst. Mg. Eng., Vol. 25, 1902-1903, London and Newcastle-upon Tyne, p. 826.

LAOS (Continued)

Mine located in Province of Kammun, Laos, in a small tributary valley of the Hinbun River. At present worked by French, has long been worked by natives. Ore occurs in limestone, no eruptives. Not in place, but little water worn. None of the ordinary minerals accompanying tin are present. Cassiterite often resembles "needle ore" of Cornwall. Cassiterite supposed to be a primary constituent of a sulphide gossan, as at Campiglia, Italy.

PELATAN, L. Les richesses minérales des colonies françaises (Asie Française).

Rev. Univ. Mines, Mét. Trav. Publ. Sci. Arts Appl. Indust., ser. 3, Vol. 54, 1901, Liége and Paris, pp. 247-249.

MADAGASCAR

BOUSE, JOHNO. Madagascar mineral and other resources.

California Journ. Tech., Vol. 4, No. 2, 1904, Berkeley, p. 61.

Copper and tin ores are mined in a small way. So far these ore deposits do not seem very extensive or rich. Some tin is exported.

DUNSTAN, WYNDHAM R. Tinstone from Madagascar.

Bull. Imp. Inst., Great Britain, Vol. 3, No. 1, 1905, London, p. 41.

The analysis of a specimen from Antananarivo gave 77.5 per cent metallic tin, but it is scarcely to be expected that when mined on a large scale such a high content of metallic tin will be maintained.

LACROIX, ALFRED. *See* No. 516.

PELATAN, L. Les richesses minérales des colonies françaises (Madagascar).

Rev. Univ. Mines, Mét. Trav. Publ. Sci. Arts Appl. Indust., ser. 3, Vol. 52, 1900, Paris and Liége, pp. 294-295.

Tin has long been known to exist in region of Ambatofangehana, and recently tin has been found in the southern part of the district of Ambohimanga.

MAINE

HITCHCOCK, C. H. State Geol. of Maine. Letter to D. W. Hendrickson.

In prospectus bound in Mining Pamphlets, Vol. 69, U. S. Geol. Surv. Library. (Letter dated Aug. 8, 1865.)

States that tin ore at Mt. Mica, Paris, Maine, is in "a very coarse granite, in a finer granite, and this cuts a coarse mica schist, the oldest rocks in Oxford Co." "Largest known cut tourmaline in the world came from this hill, and is valued at £300. It is owned by Prof. C. U. Shepard of Amherst College." A crystal of cassiterite exceeding 5 pounds in weight had been taken out. Thinks the deposit and the one at Mt. Rubelite, in Hebron, worth exploring.

———. Reputed tin discovery in Maine.

Eng. Mg. Journ., Vol. 30, 1880, New York, p. 173.

Quoted: Mg. Sci. Press, Vol. 41, 1880, San Francisco, p. 194.

Short article recording a recent discovery of tin ore at Winslow, Maine. The inclosing rock is described as a mica slate, adjacent to which is a hard quartzite band. Author states that mineralogical, geological, and physical features are identical with those common to the stanniferous districts of Europe.

MAINE (Continued)

651. HUNT, T. STERRY. Remarks on an occurrence of tin ore at Winslow, Maine.

Trans. Amer. Inst. Mg. Eng., Vol. 1, 1871-1873, New York, pp. 373-375.
Remarks by Prof. Silliman and R. W. Raymond.
Tin veins an inch or two in thickness, traverse an impure gray micaceous limestone. Gangue consists of purple fluorspar, and silvery white mica with quartz, through which the cassiterite associated with mispickel, is disseminated in small crystalline masses.

652. ———. Discovery of tin ore and emery at Winslow, Me.

Eng. Mg. Journ., Vol. 30, 1880, New York, p. 218.
Short communication regarding discovery of tin at Winslow, Me.

653. JACKSON, C. T. Sur les mines de cuivre du lac Supérieur et sur un nouveau gisement d'étain dans l'État du Maine. (Extract d'une Lettre.)

C. R. Acad. Sci., Vol. 60, 1869, Paris, pp. 1082-1083.

654. ———. Tin ore at Winslow, Me.

Proc. Boston Soc. Nat. Hist., Vol. 12, 1869, Boston, p. 267.
An account of discovery of tin at Winslow. Rock in which veins exist is a compact mica slate or gneiss, and the vein matter consists of purple fluorspar, silvery radiated mica in hexagonal prisms, and quartz.

MALAY PENINSULA

655. ANONYMOUS. Geology and mineralogy of the Malay Peninsula.

Mg. Journ. Railw. Comm. Gaz., Vol. 18, 1848, London, p. 197.
Amer. Journ. Sci. Arts, ser. 2, Vol. 6, 1848, New Haven, pp. 129-132.

656. ———. Tin in the Malay Peninsula.

Eng. Mg. Journ., Vol. 47, 1889, New York, p. 48.
Short review of a report of Belgian Consul-General.

657. ———. The production of tin in the Malay Peninsula.

Journ. Soc. Arts, Vol. 41, 1893, London, pp. 421-422.
Statistics of production for 1891. Description of Chinese methods of mining.

658. ———. The Perak tin mines.

Eng. Mg. Journ., Vol. 56, 1893, New York, pp. 268-269, illus. 1, figs. 6.
Abstract from "London Engineer" describing the Chinese method of working tin mines. The mines are not profitable when worked by expensive western methods.

659. ———. Mining in the Malay Peninsula.

Mg. Journ. Railw. Comm. Gaz., Vol. 66, 1896, London, pp. 277, 308-309.
Editorials.
Description of Peninsula, geology and minerals. Tin and gold the only metals in deposits of commercial importance. Tin deposits mostly alluvial, bedrock is kaolin, or rarely, shale or limestone, upon which is the stanniferous gravel from a few inches to 80 feet thick. A little lode mining is being carried on in Kuantan; in Pahang and at Bundi, in Tringganu. At Kuchai, in Selangor, also at Sungei Rin in Jelebu leaders and veinlets of tin ore have been found in a "greisen" similar to occurrences in Saxony and Bohemia. Thinks discovery of veins may have great future results.

MALAY PENINSULA (Continued)

660. ———. Tin mining in Perak.

Mg. Sci. Press, Vol. 76, 1898, San Francisco, p. 61.

Extract from report of the Commissioner of Lands and Mines of Perak, giving mining conditions, output, prices, etc., for 1896.

661. ———. The Malay tin industry.

Iron Age, Vol. 62, II, Dec. 8, 1898, New York, pp. 17-18.

Shows that federated Malay States will continue to be by far the largest tin producing country in the world; describes deposits, mining, etc.

662. ———. Tin of Straits Settlements.

Min. Ind. for 1898, Vol. 7, 1899, New York and London, p. 711. See No. 1287.

663. ———. Tin in the Malay Peninsula.

Min. Ind. for 1900, Vol. 9, 1901, New York and London, pp. 639-640.

While river dredging for tin has not been seriously attempted, applications for water rights to follow this method of mining are being made. Progress has been made in the development of lodes, especially in district of Kuantan, Pahang.

664. ———. Tin supplies.

Engineering, Vol. 72, No. 1872, November 15, 1901, London, pp. 684-685, 1300 words.

"Editorial on the tin supply in the Malay States, based on information given in the last annual government report and claiming that there is no cause for anxiety concerning the future supply."

Not available to the authors.

665. ———. Tin mining in Malaya.

Austr. Mg. Stand., Vol. 20, Dec. 26, 1901, Sydney and Melbourne. Serial. 1st part.

"Discusses the tin deposits in the Malay Peninsula, and the future outlook as a tin-producing region."

Vol. 21, 1902, p. 47, 2d part. Outlines advantages to be gained by the use of water power as a mining agent in Malaya. Describes the deep lead and lode mining.

First article not available to the authors.

666. ———. Tin in Malay Peninsula.

Min. Ind. for 1901, Vol. 10, 1902, New York and London, pp. 641-642.

667. ———. Mining in the Malay Peninsula.

Mg. Journ. Railw. Comm. Gaz., Vol. 72, 1902, London, p. 754.

A statement of the production and a brief description of the tin deposits of four of the Federated Malay States: Perak, Selangor, Negri Sembilan and Pahang.

668. ———. Malayan tin mining.

Austr. Mg. Stand., Vol. 30, 1903, Sydney and Melbourne, p. 665.

Reprint from "Straits Echo."

A Chinaman has applied ground-sluicing to placer tin mining and it is described as a novelty.

669. ———. Malay mining; the tin duty.

Mg. Journ. Railw. Comm. Gaz., Vol. 76, 1904, London, p. 233, 420 words.

Digest: Mg. Mag. Vol. 10, 1904, New York, p. 336.

Extract from the "Malay Mail," incorporating protest of miners' association against high advalorem duty on exportation of tin. Statistics of production and costs are included.

670. ———. The Tambum tin mine, Perak.

Mg. Journ. Railw. Comm. Gaz., Vol. 76, 1904, London, p. 626.

Mine situated 5 miles from Ipoh; owned by Mr. Leong Fee; turns out 140 piculs of ore per day. Net profits for Sept. 1904, $60,000.

MALAY PENINSULA (Continued)

671. ———. Production de l'étain dans les États fédérés malais.
Métallurgie, Vol. 35, 1904, Paris, p. 1498.

672. ———. The Straits tin mines.
Eng. Mg. Journ., Vol. 80, 1905, New York, pp. 831-832.
Brief summary of Senior Warden of Mines' report. Output in 1904, 856,238 piculs. Perak continues the premier producer of tin in Federated Malay States. Brief accounts of progress in various mining districts.

673. ———. Monazite tin ore in Federated Malay States.
Selangor Government Gazette, Sept. 14, 1906.
Review: Eng. Mg. Journ., Vol. 82, 1906, New York, p. 918.
Contains a report on a specimen of washed alluvial tin ore from the land worked by the Sempam Tin Mining Co., Pahang. The ore consisted principally of a mixture of cassiterite, ilmenite and monazite. An analysis of the ore is given.
Original article not available to the authors.

674. ———. *See* No. 673.
Quoted in Mg. Journ. Railw. Comm. Gaz., Vol. 80, 1906, London, p. 475.

675. ———. Tin production in the far East.
Eng. Mg. Journ., Vol. 82, 1906, New York, p. 963.
Treats mostly of the labor troubles in connection with mining in the Malay States and Dutch East Indies. Average output of tin in Malay States for 1905 was 4.09 piculs (534 pounds) per coolie.

676. ———. Tin dredging on the foreshore in the Malay Peninsula.
Mg. Journ. Railw. Comm. Gaz., Vol. 83, 1908, London, p. 237.
Description of the tin dredging operations in Tongkah Harbor, Siam.

676a. ———. Tongkah Harbor Tin Dredging Co.
Austr. Mg. Eng. Rev., Vol. 1, 1909, Melbourne, pp. 277-278. Illus.
Editorial on same. Austr. Mg. Eng. Rev., Vol. 1, 1909, Melbourne, pp. 347-348.
Very brief description of the tin bearing area of Tongkah Harbor, located on Puket Island, a Siamese possession on west side of Malay peninsula. Also describes work now being done by the dredging company.

676b. ———. Tin ores from the Federated Malay States.
Bull. Imp. Inst., Vol. 6, 1908, London, pp. 155-157.
Describes placer tin samples containing corundum, rutile and a small amount of rare earths, besides tin. Lode stuff carried Co, Zn and As.

676c. ———. Tin mining in Malaya.
Eng. Mg. Journ., Vol. 88, 1909, New York, p. 929.

676d. ———. Tin mining in the Federated Malay States.
Austr. Mg. Stand., Vol. 43, 1910, Sydney and Melbourne, pp. 169-170, illus. I.
Deals with mining and treatment methods.

677. BALFOUR, JOHN F. Tin in the Malay Peninsula.
Journ. Soc. Arts, Vol. 55, 1907, London, pp. 505-507.
Treats of the general features of the peninsula, geology, and tin deposits. The tin is considered under: Lode mining, impregnations (contact deposits and stockworks) and alluvial deposits, as to the manner of occurrence and method of working.

678. BECHER, H. M. Mining in the Malay Peninsula.
Trans. Inst. Mg. Met., Vol. 1, 1892-1893, London, pp. 78-107, discussion, pp. 131-141.
Treated under heads: The tin formation; the Malay gold-bearing formation; the Chinese system of mining; the character of the alluvial; modern methods vs. Chinese; pumping methods; the machinery employed; general conclusions; prospects of the Malayan tin fields.

MALAY PENINSULA (Continued)

BECK, RICHARD. *See* No. 1299.

79. BENEDICT, WM. DE L. Tin in the Malayan region.

Min. Ind. for 1892, Vol. 1, 1893, New York and London, pp. 446-450.

Perak produces two-thirds of tin production of the Straits, and one-third of that of the world. Description of Perak deposits, methods of mining. Tin deposits of Island of Sumatra treated. Assays given.

BROWN, A. SELWYN. *See* Nos. 1307 and 1308.

80. CLIFFORD, HUGH. Tin in Malaya.

Austr. Mg. Stand., Vol. 29, 1903, Sydney and Melbourne, p. 250.

Extract of a lecture delivered before the Royal Colonial Institute, Dec. 9, 1902. Deals with tin resources of the Malay States.

81. COLLETT, OCTAVE J. A. L'Étain. Étude minère et politique sur les Etats fédérés malais.

1903, Brussels, p. 196, map 1, and plates.

On tin in the Malay Peninsula. Divided into six parts: (1) Geography. (2) History. (3) Geology. (4) Methods of mining tin. (5) Methods of mining and smelting tin. (6) Legislation regarding tin. Production, prices, etc. Geology. General structure of the country. Popular explanation of formation of placers from veins. Very little description of the veins or of the placers themselves. Cassiterite accompanied by grains of quartz, hematite, fluorite, pyrite, tourmaline and feldspar.

81a. CORNUBIAN. Lode mining in the Malay States.

Mg. Journ. Railw. Comm. Gaz., Vol. 84, 1908, London, p. 622.

Letter in which a correspondent states that the lode mines of Pahang are among the big tin mines of the world, and gives figures to support his statement.

82. CRAMER, CARL. Das Zinnerz und seine Gewinnung auf der Halbinsel Malacca.

Oest. Zeitschr. Berg. Hütt., Vol. 42, 1894, Wien, pp. 543-545, pl. 20.

Digest translation: Trans. Fed. Inst. Mg. Eng., Vol. 10, 1895-1896, Newcastle-upon-Tyne and London, p. 589.

Thickness of ore-bearing deposit (karang) up to 3¼ feet. Overburden up to 33 feet, average 6½ to 10 feet. Tin ore in karang varies up to 15 per cent, may be barren. Pays with as little as 0.5 per cent. French company tried to dredge in river Muar, but failed. Impurities: iron, wolframite, ilmenite. 77.15 pounds tin per head per month average production.

83. CROOCKEWIT, H. Tin mines of Malacca.

Journ. Ind. Arch. East. Asia, Vol. 8, 1854, Singapore, pp. 112-133.

Translated from Tijdschr. Ned. Ind., Nov. 1851, Batavia.

Not available to the authors.

D'ACHIARDI, ANTONIO. *See* No. 1313.

DAVIES, D. C. *See* No. 1317.

84. DE LA CROIX, J. ERRINGTON. Some account of the mining districts of Lower Pêrak.

Journ. Straits Branch Roy. Asiatic Soc., June 1881, Singapore, pp. 1-10, section 1.

The region of Lower Pêrak comprises numerous mining districts, which can be placed under following heads: 1. Sungei Kinta District. 2. Sungei Bâtang Pâdang District. 3. Sungei Bidor District. The geology of these districts is given, the

MALAY PENINSULA (Continued)

occurrence of tin ore, and the manner of mining by Chinese and Malays. Author believes the mining in all of the districts is in its infancy, and with better roads, and the clearing of streams, rendering transportation easier, many of the deposits now neglected could be worked with profit. There is at least 7,680 acres of actual alluvial ground, which under ordinary circumstances, will afford work to 25,000 miners for the next hundred years.

685. ———. Les mines d'étain de Perak.

Arch. Miss. sci. litt., ser. 3, Vol. 9, 1882, Paris, pp. 1-78.

Digests: Nature, Vol. 28, 1883, London, pp. 202-203; Sci. Amer. Suppl., Vol. 16, 1883, New York, pp. 6368-6369.

Memoir result of seven months exploration in the Malay State of Perak. Perak, although only 95 by 50 miles in dimensions, having an area of less than 5000 square miles, has long been known as a tin producing country, but only since the influx of Chinese has it been of first rate importance. Mines worked at present, chiefly alluvial, water-courses being filled with sand and gravel deposits to a depth of 20 or 30 feet, resting upon a floor of pure china clay, apparently derived from decomposition of the granitic rocks. Geological description necessarily imperfect, owing to the dense tropical vegetation which covers the entire country. Author has been able to establish the presence of numerous quartz veins traversing the granite which is coarsely porphyritic in the center and largely charged with tourmaline at the edges of the masses, reproducing the conditions to be found in the northwestern tin districts of Cornwall. Ore very pure, free from wolframite, arsenic, etc., which is troublesome to the Cornish miner. No vein mines have yet been opened. Methods of working, very primitive. Great improvement of mining conditions under British rule.

686. ———. Le royaume de Pérak.

Bull. Soc. Géogr., ser. 7, Vol. 4, 1883, Paris, pp. 333-354.

Describes the country in general, economic conditions, mines and miners.

687. DERRICK, W. H. Notes on lode tin mining in the Malay Peninsula.

Trans. Inst. Mg. Met., Vol. 7, 1898-1899, London, pp. 12-16. Discussion, pp. 16-19.

Abstract: Eng. Mg. Journ., Vol. 68, 1899, New York, pp. 784-785.

Description and cost of working the mines of Kuantan, Pahang, the principal lode mine of the Federated Malay States. These mines, so report says, were worked 100 years. The open cast system was the only one adopted by the old miners. Under native management (at least within recent years) the mines were not a financial success. Good outlook for increased output under European management.

688. DOYLE, PATRICK. Tin mining in Larut.

Mg. Journ. Railw. Comm. Gaz., Vol. 48, 1878, London, pp. 1191, 1219, 1247.

Reprinted in book form, 1879, London and New York.

A series of three articles giving a brief historical summary of Larut, a subsidiary district of Perak; description of the geological features of the country, and mineralogical productions. Describes miners (Chinese), modes of living, prosperity, manner of mining and its difficulties.

689. ———. On some tin deposits of the Mayalan Peninsula.

Quart. Journ. Geol. Soc. London, Vol. 35, 1879, London, pp. 229-232.

"All the ore worked up to the present time has been found in the alluvium derived from the mountain ranges; that is, in mining language, in stream works. The ore has been traced up to veins in the rock, but these have not hitherto been worked. The tin beds are composed of the débris of granitic rocks mixed with the ore."

690. DIJK, P. VAN. Tinontginning in het district Larut Perak, Gouvernement Straits Settlements.

Jaarb. Mijnw. Ned. Oost-Indië, 1883, II, Gemengde, Tech., Amsterdam, pp. 115-136.

MALAY PENINSULA (Continued)

DYKES, F. J. B. Tin mining in Malaya.

Austr. Mg. Stand., Vol. 32, 1904, Sydney and Melbourne, p. 137.

Extract from Senior Warden of Mines' report for 1903. Statistics of population employed in tin mining, output per annum, earnings of laborer, etc. Tronoh and Tambum are mentioned as the two richest mines in Malaya. Brief history of Tambum.

———. Report of the administration of the mines department, and on the mining industry for the year 1903.

Perak Gov. Gaz, Suppl., Vol. 17, No. 22, 1904, Kuala Lumpur, pp. 1-11.

Treats of tin mining and the output.

———. Federated Malay States. Report on the administration of the mines department and on the mining industry for the year 1904. [Tin and gold.]

Perak Gov. Gaz. Suppl., July 14, 1905, Kuala Lumpur, pp. 1-9.

ELLIS, THOS. F., and MCKILLOP, JOHN. *See* No. 1530.

FAWNS, SYDNEY. Tin lode mining in Tringganu.

Mg. Journ. Railw. Comm. Gaz., Vol. 76, 1904, London, p. 377.

Abstract: Lakes, Arthur, Min. Rep., Vol. 50, 1904, Denver, p. 500.

"Describes the mode of occurrence and work done up to present time in this part of the Malay Peninsula."

———. *See* No. 1320.

FLOWER-ELLIS, T. A brief account of the Malay tin industry.

Proc. Chem. Met. Soc. South Africa, Vol. 2, February, 1897-September, 1899, Johannesburg, pp. 5-18.

Treats of the geology of the Malay Peninsula, properties of cassiterite, methods of mining, richness of deposits, purification of the ores, Chinese method of smelting tin ores, European method of smelting tin ores, refining the rough metal, tests for quality of tin, Swaziland tin fields.

HAMPTON, J. H. The tin deposits of the Straits.

Iron Age, Vol. 38, 1886, New York, p. 1.

Description of the country, the tin deposits, the Chinese methods of mining and smelting, and output from 1876-1884.

———. Tin deposits of the State of Perak, Straits Settlement.

Trans. Min. Ass. Inst. Cornwall, Vol. 1, 1887, Camborne, pp. 143-152. Map.

A short descriptive article.

———. On the occurrence of tin.

Trans. Geol. Soc. South Africa, Vol. 4, 1899, Johannesburg, pp. 37-40.

Malay Peninsula tin deposits were first visited by author in 1882. The contour of country and existence of forests made geological observations difficult. Stanniferous gravels extend over a very large area. Tin was raised by Chinese as long ago as 1793. Lode tin is attracting attention in State of Pahang.

HUGHES, T. W. H. *See* No. 1507.

HUME, W. J. P., and DYKES, F. J. B. Report of proceedings of the mining conference held at Ipoh, Perak, Federated Malay States, Sept. 23 to Oct. 6, 1901.

1902, Taiping, pp. 1-64, pl. 5, fol.

LAKES, ARTHUR. *See* No. 694.

MALAY PENINSULA (Continued)

699. LOCK, C. G. WARNFORD. Tin mining and milling in Tringganu.

Mg. Mag., Vol. 13, No. 4, 1906, New York, pp. 290-294, pls. 7. 1400 words.

Short general description of tin mining conditions in northeastern Malay States.

No productive mines in granite, but some in overlying slates. Tin veins often have no quartz in them, being solid cassiterite. No fluorite or tourmaline. Much monazite and xenotime with some zircon and ilmenite in the stream gravels.

700. ———. Tin in Tringganu.

Mg. Journ. Railw. Comm. Gaz., Vol. 79, 1906, London, p. 182.

Gives outline of geography and geology of Tringganu, and describes both the lode and alluvial deposits of the State. The veins are mostly in shales overlying granite.

For original article see No. 699.

701. ———. Mining in Malaya for gold and tin.

1908, London,

Not available to the authors.

702. LOUIS, HENRY. Tin in the Malayan region.

Min. Ind. for 1895, Vol. 4, 1896, New York and London, pp. 571-573.

Digest of article from Mining Journal Railway and Commercial Gazette. See No. 1340.

703. ———. Die Zinnseifen der Halbinsel Malakka.

Zeitschr. prakt. Geol., 1896, Berlin, pp. 233-234.

Taken from "Western Daily Mercury," March, 1895.

———. *See* No. 1340.

704. LOW, JAMES. Observations on the geological appearances and general features of portions of the Malayan Peninsula and of the countries lying betwixt it and 18° N. lat., pp. 128-162.

Book not available to authors, but a brief digest is found in Glean. Sci., Vol. 1829, Calcutta, pp. 223-224.

Tin-bearing ground extends in a continuous line from the southern extremity Peninsula to about 15° N. lat. No mines discovered beyond this. Mines are pits from twelve to twenty feet deep. Ore generally in round or oblong masses, si well-defined crystals, in matrix of quartz, or bedded in masses resembling h decomposed granite. Brief description of metallurgical processes used.

704a. MARKS, E. SEABORN. Mining in the Malay States.

Mg. Sci. Press, Vol. 98, 1909, San Francisco, pp. 31-36, illus.

"A description of the climatic conditions of the country and the method mining and concentrating tin ore."

McKILLOP, JOHN, and ELLIS, THOS. F. *See* No. 1530.

705. MEUNIER, STANISLAS. Examen chimique d'eaux minérales provenant d Malaisie minerai d'étain de formation actuelle.

C. R. Acad. Sci., Vol. 110, 1890, Paris, pp. 1083-1085.

Author "found 0.5 per cent of SnO_2 in an opaline deposit, resembling geyserite from a thermal spring in Selangor." See No. 726b.

705a. MILES, EDWARD T. Notes on Tongkah tin dredging.

Austr. Mg. Stand., Vol. 42, 1909, Sydney and Melbourne, p. 60.

Describes the deposits of tin and difficulties experienced in dredging in Tongk Harbor, situated on northeast side of Tongkah Island (Junk Ceylon).

MALAY PENINSULA (Continued)

RGAN, J. DE. Note sur la geologie et sur minière du royaume de Perak t des pays voisins.

Ann. Mines, ser. 8, Vol. 9, 1886, Paris, pp. 368-442, pls. 8, 9, 10.

Discusses the geography, the geology and the tin mines of Perak. Also treats the main workings individually, the manner of exploitation, metallurgy, the Chinese companies, the mining laws and the statistics.

SS, E. W. Observations on the distribution and economic value of in ores in the Malay Peninsula.

Rep. Rugby School Nat. Hist. Soc. for 1890 (1891), Rugby, pp. 17-21, map.

Digest from Ann. Brit. Geol., 1891, London, p. 377.

"A general notice of the stream tin of Banca and the vein tin of Perak."

WLAND, D. H. Tin in Malay States.

Min. Ind. for 1903, Vol. 12, 1904, New York and London, pp. 330-331.

Short article dealing with the Malayan tin trade during 1903.

YES, H. HERBERT. Tin deep leads in Selangor.

Mg. Journ. Railw. Comm. Gaz., Vol. 79, 1906, London, p. 690.

Reprint: Eng. Mg. Journ., Vol. 82, 1906, New York, p. 1.

Gives a description of the alluvial tin deposits of the Serendah Valley, Selangor. The writer states that these once famous fields have been practically abandoned by the Chinese. They leave as soon as the shallow and easily worked deposits near exhaustion. Believes Europeans will have to take up the work in the deep deposits.

BECK, PETER. A voyage to China and the East Indies.

1771. London, Vol. 1, p. 244 (English edition); p. 204 (German edition).

Briefly mentions that "tin comes in small pieces from Pegu and Jahor."

VEN, FRANK. Mining in Perak.

Trans. Inst. Mg. Met., Vol. 6, 1897-1898, London, pp. 51-87.

Abstract: Min. Ind. for 1897, Vol. 6, 1898, New York and London, pp. 641-644.

Extract: "Chinese tin smelting," Coll. Guard., Vol. 74, 1897, London, p. 931.

Area, population, statistics, manner of mining, etc. Describes the Chinese system of smelting tin in a blast furnace.

——. A review of the tin industry of the Malay Peninsula (up to he end of 1889).

Min. Ind. for 1900, Vol. 9, 1901, New York and London, pp. 646-656, map 1.

Describes the occurrence of tin ore in the Malay Peninsula, the general geology of the country, and the prices obtained for tin. Also treats of the mining conditions and the future prospects of the industry.

ARKES, CHAS. R. Surface tin mining in the Malay Archipelago.

Proc. Inst. Civ. Eng., Vol. 115, pt. I, 1894, London, pp. 352-354. Abridged.

Malay alluvial tin deposits are briefly described, and methods of mining are given in considerable detail.

ENROSE, R. A., JR. Tin deposits of the Malay Peninsula, with special reference to those of the Kinta districts.

Journ. Geol., Vol. 11, 1903, Chicago, pp. 135-154, figs. 9, pls. 4.

Digest: Zeitschr. prakt. Geol., Vol. 11, 1903, Berlin, pp. 278-279. Neues Jahrb. Min., 1905, I (Ref.), Stuttgart, p. 100.

Abstracts: Min. Ind. for 1902, Vol. 11, 1903, New York and London, pp. 590-593; Eng. Mg. Journ., Vol. 75, 1903, New York, pp. 926-928, map, illus. 3.

MALAY PENINSULA (Continued)

The geographical position of the Malay tin regions is given and the general geology of the Malay Peninsula. The Kinta district is then taken up, its location described, and the occurrence and nature of alluvial tin ores of the district are treated. The accompanying minerals are also noted. The occurrence of tin ore in the rocks, the origin of the deposits and the commercial features are discussed.

PHILLIPS, J. A., and LOUIS, H. *See* No. 1350.

715. PIKE, E. R. Mining in Perak, Straits Settlements.

Trans. Mg. Ass. Inst. Cornwall, Vol. 3, 1892, Camborne, pp. 194-201, discussion pp. 201-206.

Gives a brief general description of Perak, the location of the tin-placers and the mining methods of the Chinese. Also describes the Kinta tin lodes and Malayan tin-smelting practice.

716. PLACE, JOHN. Tin mining in the Malay States.

Engineering, Vol. 82, 1906, London, pp. 281-284, pl. 1.

A very general article giving a description of the country and trade conditions, with short descriptions of mines and smelting. Prophesies further development and increase of output.

717. RATHBORNE, AMBROSE B. Camping and tramping in Malaya, fifteen years' pioneering in the native States of the Malay Peninsula.

1898, London, pp. 117-166, 333-334.

Pages 117-166: General description of mines (wholly untechnical), labor, social, economic conditions, fuel supply, roads, etc. 333-334, geology: "Upheaval of the granite"; "more violent" between 3° and 6° than between 1° and 3°. Limestone occurs in the northern half of the country. Near Thaiping, borings show country to have recently sunk over a hundred feet. Old cannon found at Larut 30 feet below surface in tin mine. Stone implements frequently found, but no mammalian bones in the gravels. A hoard of Portuguese coins of the 15th century was dug up at Kinta.

718. RITTER, CARL. Die Erdkunde.

Vol. 5 (Die indische Welt), 1835, Berlin, pp. 77-79, 246.

Treats of the tin of the Malayan Peninsula.

719. ROLKER, CHARLES M. The tins of Banca and Billiton.

Eng. Mg. Journ., Vol. 28, 1879, New York, p. 338. An abstract from an article by E. Reyer. See No. 117.

———. *See* No. 1357.

720. ROSS, D. Notice of some tin ore from the coast of Tenasserim.

Glean. Sci., Vol. 1, 1829, Calcutta, pp. 143-144.

Description of some stream tin from Chanda, half way between Mergui and Tav[illegible].

721. RUMBOLD, WM. R. The tin deposits of the Kinta Valley, Federated Malay States.

Amer. Inst. Mg. Eng., Vol. 37, 1906, New York, pp. 879-889, figs. 1-4.

Reprint: Mg. Journ., Vol. 80, 1906, p. 460.

General description of Kinta Valley; alluvial tin deposits; lode deposits; (a) those in granite, (b) those in limestone; origin of the deposits.

States that this district is probably, at the present time, the richest alluvial tin district in the world.

MALAY PENINSULA (Continued)

UNDERS, W. T. Tin mining in the Straits Settlement.

Trans. Inst. Mg. Eng., pt. 4, Vol. 27, 1904, London and Newcastle-upon-Tyne, pp. 343-350.

Digest: Mg. Mag., Vol. 11, No. 1, 1905, New York, p. 71.

Reprint: Mg. Journ. Railw. Comm. Gaz., Vol. 75, 1904, London, p. 661.

About 60 per cent of the world's supply of tin comes from Straits Settlement. In the past most of it has been obtained from alluvial deposits, and while the placers appear to be unfailing, much attention is now given to lode mining. Alluvial mining is carried on largely on the west side of the Peninsula, while lode mining is confined to east side.

RIVENOR, J. B. A preliminary report on the geology of the neighborhood of Taiping, Perak.

Perak Gov. Gaz., Suppl., Vol. 17, No. 3, January 15, 1904, Kuala Lumpur, pp. 1-14, 13,000 words.

Part I. Physical features, igneous rocks, sedimentary rocks, alluvial deposits, faults and mineral lodes, weathering.

Part II. Geological history, mining prospects.

——. Federated Malay States. Geologist's Report for 1904 (Tin).

Perak Gov. Gaz. Suppl., July 14, 1905, Kuala Lumpur, pp. 7.

The material in this article appears in the same author's "Geologist's Report of Progress," September, 1903-January, 1907. See No. 726.

Not available to the authors.

——. Alluvial and lode tin in Malaya.

Mg. Journ. Railw. Comm. Gaz., Vol. 78, 1905, London, pp. 273, 2400 words.

"From the annual report of the Federated Malay States. Describes three mines of detrital tin associated with limestone, gives information of the tin lodes, and briefly discusses the origin of the deposits."

——. Geologist's report of progress, Sept., 1903-Jan., 1907.

Federated Malay States Government Press, Kuala Lumpur, 1907, pp. 1-44, sketch map 1.

Reprint: Mg. Journ. Railw. Comm. Gaz., Vol. 81, 1907, London, pp. 781-782, 793, 843-844, 866-867.

A summary of work done embracing that published in the Perak Government Gazette except report on geology of Sarawak. First 18 pages deal with structural geology. Describes tin lodes of Kuantan (Sungei Lembing); Bundi, Kemaman; Machi tin field; mines in the Main Range, including the Telom district, Tras, Bentong, Gunong Gapis, Bukit Fraser and neighboring places; Chin Chin and Tanjong Serai, Malacca; stockworks at Bruseh and Tanjong Malim; tin ore in limestone at Changkat Pari, Ayer Dangsang, Siak and Jesophat's Valley; alluvial mines of Tronoh and Sungei Besi, Perak.

——. Geologist's annual report for 1908.

Federated Malay States, Kuala Lumpur, 1909, pp. 2-7.

The Ayer Dangsang pipe changed at a depth of 170 feet to a vein 5 to 6 feet thick with the same mineral association—abundant sulphides in a calcite matrix, with fluorite and a little quartz. In the Lahat pipe the original calcite and sulphides were dissolved and after a partial concentration the pipe was recemented with calcite from the limestone walls.

Scheelite with abundant tourmaline, a little pyrite, traces of copper and arsenic, occur in a quartz vein at Salak North, Perak. Scheelite occurs in a number of Pahang tin mines.

Cassiterite occurs with tremolite in a pipe at Lahat. Describes a stockwork of minute veins which is a type of many deposits in the Kledang Range.

MALAY PENINSULA (Continued)

Some of the alluvial tin ore contains metallic copper in fine sharp crystals.

Small seams of lignite standing vertically, occur in the tin gravels. Leaching of the underlying limestone has let the gravels down until they are, in places, on edge, and have been covered over by horizontal beds.

726b. ———. **The origin of tin deposits.**

1909, Kuala Lumpur, pp. 11.

Also, Mg. Journ. Railw. Comm. Gaz., Vol. 85, 1909; London, pp. 307, 340.

Reviews the commonly accepted theories concerning the deposition of tin minerals. He doubts the analysis of Meunier showing tin oxide in siliceous sinter from Ayer Panas (see No. 705), and states that his examination of deer-horns similar to those supposed by J. H. Collins to have been partly replaced by SnO_2, showed no tin.

Numerous tin deposits of the Malay Peninsula are in limestone or clay-slate, but granite is supposed to be close at hand in each place. At Bundi, in Kemaman, a tin deposit in which the SnO_2 is in small yellow needles, carries no tourmaline, but there is some axinite.

Most of the deposits are veins, large or small, but there are a few tin-bearing pegmatites in the Malay Peninsula.

Shows that in many places in the Malay Peninsula, especially in the limestone region, there is very little tourmaline, but generally much fluorspar with the tin deposits. He believes fluorine to be more important than boron in the genesis of tin minerals. There is also much arsenopyrite in the limestone, more than when the deposits are in granite.

727. SLACK, W. E. **Malay tin mines. Handbook giving particulars of mining companies working in the Malay Federated States.**

1907 (?), London.

Not available to the authors.

728. STEPHENS, F. J. **Mineral features of Pahang, Malay Peninsula.**

Trans. Inst. Mg. Met., Vol. 9, 1900-1901, London, pp. 419-424.

Describes the physical conditions under which mining must be carried on, transportation facilities and economic details; the geology of the country; the vein systems; the workings of individual companies; tin and gold ores, and their richness.

729. STOKES, RALPH, S. G. **A series of articles on Malay tin fields.**

Mg. World, Vol. 25, 1906, Chicago. Illustrated.

1. Industrial position of Malay tin fields. Sept. 1, 1906, pp. 234-235.
2. Geology of Malay tin fields. Sept. 8, 1906, pp. 262-263.
3. Malay tin fields. Oct. 6, 1906, pp. 424-425.
4. Geology and treatment of tin in the Malay fields. Nov. 10, 1906, pp. 572-573.

730. ———. **Mines and minerals of the British Empire. Being a description of the historical, physical and industrial features of the principal centers of mineral production in the British Dominions beyond the seas.**

1908, London, pp. 65-75 and others, with a number of plates.

The Malay States tin fields are treated in chapters 6 and 7. A review of the world's sources of tin supply is given, after which he discusses the labor available, the production of tin in the different states; taxation and other heavy charges of government; the geology, and the different classes of deposits, both in place and alluvial. Chapter 7 is devoted to methods of mining and a description of alluvial mines.

A chapter is devoted to the Mt. Bischoff tin mine, Tasmania, and another to the northeastern tin fields of that Province. The tin deposits of New South Wales, Transvaal, Cape Colony and Northern Nigeria receive passing mention.

MALAY PENINSULA (Continued)

'ETTENHAM, FRANK. About Perak.

Published by "Straits Times." 1893, Singapore.
Book not available to the authors.

'ETTENHAM, F(RANK) A. Annual report of the State of Perak for the ear 1893.

Taiping, Perak, pp. 53. Progress of tin mining in Perak, and information concerning output.

YLOR, WILLIAM. Tin mining in the Federated Malay States.

Eng. Mg. Journ. Vol. 82, 1906, New York, p. 529.
Short extract from Ann. Rep. for 1905.
Figures given, showing output from various mines. "The acting Senior Warden sees no cause for alarm in the decreased output, and is of the opinion that no evidence is forthcoming to show that the stanniferous deposits of the country are nearing exhaustion."

NISON-WOODS, J. E. Geology of the Malayan Peninsula.

Nature, Vol. 30, 1884, London, p. 76.
Notes caves in limestone with deposits of "tin sand," which are 1000 feet above the plain; now exposed in precipices and reached by steps cut in the rock. Show extent of erosion.

——. Physical geography of the Malayan Peninsula.

Nature, Vol. 31, 1884, London, pp. 152-154.
"The tin deposits hitherto found are all stream tin, no lodes have yet been worked . . . . Though tin has been worked for centuries, only a comparatively small portion of the country has been worked out or worked at all. I consider that the deposits in Perak are practically inexhaustible."

——. Explorations in Pahang.

Nature, Vol. 33, 1885, London, p. 32.
Refers to a peculiar coinage of tin "shaped for the most part like an old fashioned square ink-stand."
Short reference to tin-bearing gravels.

——. Report on the geology and physical geography of the State of 'erak.

Proc. Linn. Soc. New South Wales, Vol. 9, 1885, Sydney, pp. 1176, 1186, 1189, 1190, 1192, 1203. Tin mines at Thaiping, Assam Kumbang, Kamunting, Salak, Pappan, Poussin, Lahat, Goping, Tecca, Kampar River, Kuala Dipang, Dindings and Selama are described.

EACHER, W. H. Mining tin.

Perak Gov. Gaz. Suppl., Vol. 17, No. 22, 1904, Kuala Lumpur, pp. 1-9. Report for 1903. 3 charts showing output of tin and iron ore pp. 40-43.
Reprinted: Board of Trade Journal, Vol. 66, 1904, p. 17.
Description of labor conditions and supply, manner of working, wages, contracts, etc., and mode of operating mines.

EMENHEERE, H. SEYMOUR. Tin in Tenasserim.

Mg. Journ. Railw. Comm. Gaz., Vol. 40, 1870, London, p. 919.
Extract of address delivered before Royal Geological Society of Cornwall. The matter is largely the same as that in the report of his brother, Geo. Borlase Tremenheere, on the "Tin of the Province of Mergui in Tenasserim, in the northern part of the Malay Peninsula."
Besides the stream tin found along the banks of the creeks, there is a rich vein of tin 3 feet wide in the side of an isolated hill, about eleven miles from Mergui. The hill consists almost entirely of decomposed granite. Crystals of cassiterite occur thickly imbedded in pure kaolin.

MALAY PENINSULA (Continued)

740. VERCOE, CHAS. Tin deposits in the Malay Peninsula.

Mg. Journ. Railw. Comm. Gaz., Vol. 50, 1880, London, p. 904.

Brief description of the mines near Malacca, at Quaila Lumpor and Laroot, and of methods used by Chinese in working them.

741. VERCOE, H. B. Tin deposits of the Straits.

Mg. Journ. Railw. Comm. Gaz., Vol. 56, 1886, London, p. 1277.

Treats briefly of alluvial deposits of Muntaha District of Johore, expresses a belief that tin lodes exist in the surrounding hills, which would prove very productive.

742. VIATOR. A trip to the Johore River (tin mines).

Not. Indian Archipelago Adj. Countr., 1837, Singapore, pp. 265-266, map.

Popular article. Visited tin mines at village of Gongong, which were formerly worked by followers of the Sultan. Smelting furnace now in ruins. Ore about 12 feet under surface, in a stratum of coarse "quarry sand," mixed with white clay. Did not seem to be very productive mines. Country very unhealthful.

743. W——. Der Zinnhandel der malayische Halbinsel.

Oest. Zeitschr. Berg. Hütt., Vol. 51, Wien, 1903, p. 645.

744. WRAY, LEONARD, JR. Tin in the Straits of Malacca and Tenasserim.

Mg. Journ. Railw. Comm. Gaz., Vol. 44, 1874, London, p. 378.

Extract from his lecture "The Settlement on the Straits of Malacca," delivered before Royal Colonial Institute, March 24, 1874. Discussion as to whether the early Phœnicians first got their tin in India or Cornwall.

745. ———. Physical geography of the Malayan Peninsula.

Nature, Vol. 31, 1885, London, p. 459.

A communication correcting what he considers to be errors in an article by J. [illegible] Tenison-Woods in "Nature," Vol. 31, pp. 152-154, 1884.

Bears upon the geology of the tin deposits.

746. ———. Alluvial tin prospecting: including tables for checking the accuracy of bore holes, and for estimating the amount, richness and value of the ore obtained from them.

Perak Mus. Notes, No. 2, 1893, Taiping, pp. 1-114.

747. ———. Some account of the tin mines and the mining industry of Perak.

Perak Mus. Notes, No. 3, 1894, Taiping, pp. 1-24, table 1, pls. 4, 5, giving diagrams.

The first three chapters of a continued article upon tin in Perak, the other numbers of which are not available to the authors. In this installment the history and statistics of the Malayan tin trade, the geology of the deposits, a description of mines, and native uses of tin are given.

MASSACHUSETTS

748. HITCHCOCK, ED. Tin in Massachusetts.

Amer. Journ. Sci. Arts, ser. I, Vol. 16, 1829, New Haven, pp. 188-191.

Brief review: Jahrb. Min. Geogn. Geol. Petr., 1830, Heidelberg, pp. 316-317.

Letter written to editor of Amer. Journ. Sci. Arts. Writer sent specimens from Goshen, Mass., of what he thought to be first tin found in the United States.

749. HITCHCOCK, EDWARD. Report on the geology of Massachusetts examined under the direction of the Governor of that state during the years 1830-1831.

Amer. Journ. Sci. Arts, ser. 1, Vol. 22, 1832, New Haven, pp. 62-63.

Tin at Goshen described.

MASSACHUSETTS (Continued)

ESCHEMACHER, J. E. Description of the oxide of tin found at the tourmaline locality, Chesterfield, Mass.

Report Association American Geologists and Naturalists, 1840-1842 (1843), Boston, pp. 296-297.

A. A. Hayes, to whom a portion was submitted for examination, says: "From these experiments it appears that the mineral is a nearly pure oxide of tin, its hardness and closeness of texture, as indicated by its high lustre, exceed those of any specimen I ever examined."

MEXICO

GUILERA, José G. Bosquejo geológico de Mexico.

Bol. Inst. Geol. Mexico, Nos. 4, 5, 6, 1897, Mexico, pp. 234-235.

A note in which he states that tin ore occurs in small veins in rhyolite, accompanied by hematite, topaz, and durangite. Rhyolites of Upper Tertiary age.

——. Catálogos sistemático y geográfico de las especies mineralógicas de la República Mexicana.

Bol. Inst. Geol. Mexico, No. 11, 1898, Mexico, pp. 83-84.

Tin is found in the following states: Aguas Calientes, Guanajuato, Jalisco, Querétaro, Sonora, Durango, Hidalgo, Puebla, San Luis Potosi, Zacatecas.

——. Geographical and geological distribution of the mineral deposits of Mexico (tin).

Trans. Amer. Inst., Mg. Eng., Vol. 32, 1902, New York, pp. 506-507.

"The tin deposits of Mexico are of two classes: Those of the Tertiary, and the alluvial placers of the Quarternary. . . . . In Mexico the characteristic association of minerals and rocks is, so we might say, that of the latest tin-veins of the Tertiary, in which are found crystallized hematite, topaz and in some cases wolframite and durangite. The associated rocks are Pliocene rhyolites and rhyolitic tufa."

LLEN, D. K. Tin in Baja California, Mexico.

Mg. Journ. Railw. Comm. Gaz., Vol. 54, 1884, London, p. 1194.

Gives an account of a piece of cassiterite weighing 314 pounds broken from ledge, brought in by Indians, source unknown. Another vein said to give 18 to 38 per cent tin from picked samples. Pay streak 2 to 4 feet wide. Found in same range or belt with same formation as that of the Temescal (Cal.), tin mines.

NONYMOUS. Tin deposits of Mexico.

Mg. Journ. Railw. Comm. Gaz., Vol. 54, 1884, London, p. 1412.

Deposits occur at small town of Coneto, about 90 miles northwest of Durango. Ore is principally red and black cassiterite of extreme purity, found both in veins and placers. "Sulphuret of tin," similar to that of Cornwall has been found in one part of the mountains, while arseniate of tin, also very finely divided red ophite of tin, are found in many veins.

——. Tin deposits of Durango, Mexico.

Eng. Mg. Journ., Vol. 48, 1889, New York, p. 80.

Describes briefly the tin deposits near Coneto, Durango.

——. Mines in the State of Guerrero, Mexico.

Mg. Journ. Railw. Comm. Gaz., Vol. 76, 1904, London, p. 556.

Extract from Bull. Official Ministerio de Fomento. In describing the mines in the district of Taxco, tin is mentioned as occurring at Acamistla and Coapango.

MEXICO (Continued)

758. ———. Tin in Mexico.

Eng. Mg. Journ., Vol. 80, 1905, New York, pp. 519-520, 1500 words.

"The tin properties now under development are 5 in number: La Esperanza, Tinnit, La Santa (sic) Francisco, La Minita and Los Dos Amigos. The tin at La Esperanza occurs in threads or stringers in the vein. When development work was started on property, the first stringer discovered was only 1-64 inch thick, but in uncovering the vein, stringers ranging from ¼ to ¾ inch thick were encountered and about 800 pounds of tin ore running 75 per cent tin was taken out. An assay across the vein runs from 2 to 4 per cent tin, while the ore as sorted by natives runs from 55 to 65 per cent and by concentration it can be brought up to 75 or 85 per cent tin.

759. ———. Mexico's first tin ingot.

Mo. Bull. Int. Bur. Amer. Repub., Vol. 21, Sept. 1905, Washington, D. C., p. 862.

States that although stream tin has been produced in Mexico for many years, the first ingot of lode tin has only recently been smelted. Gives a few details of a tin deposit at Aguas Calientes.

760. ———. Tin in Mexico.

Mg. World, Vol. 25, 1906, Chicago, p. 301.

"The tin-bearing area extends from south of Aguas Calientes to north of Durango on the eastern side of the Sierra Madre range. The localities are widely separated and according to reports, quite different in geology and ore occurrence."

761. Barcena, Mariano. Tratado de geologia elementos aplicables á la agricultura, á la ingenieria á la industria.

Bol. Secr. Fom. 1886, Mexico, p. 146.

Tin occurs in veins in Mesa de los Caballos in Zacatecas, and in alluvium in Lagos and other localities.

762. Barriga, Manuel Diaz. Mining in Mexico.

Mg. Journ. Railw. Comm. Gaz., Vol. 77, 1905, London, p. 631.

Tin bearing ground is found in many portions of the Republic, but the deposits of the Coneto region in Durango are the most important. Occur in calcareous trachite. Concentrated ores, mostly in form of oxides, yield from 35 to 75 per cent of metal.

Beck, Richard. *See* No. 1299.

763. Benedict, Wm. De L. Tin in Mexico.

Min. Ind. for 1892, Vol. 1, 1893, New York, pp. 451-452.

"Tinstone has been found in Mexico at numerous widely separated localities. None of the deposits have been systematically or extensively exploited except those of Durango, where the ore is found to occur in small but frequently very rich pockets in ill-defined veins in trachite-porphyry, which is the common country rock."

764. Bergemann, C. Zinnstein von Xeres in Mexico.

Neues Jahrb. Min. 1857, Stuttgart, p. 395.

Gives an analysis of tin ore from Xeres, Mexico.

765. Bretherton, H. G. The tin deposits of Mexico.

Mg. World, Vol. 27, 1907, Chicago, pp. 685-686.

"Notes on the history and present standing of the tin deposits which are situated in and about the border region between the states of Jalisco and Aguas Calientes."

766. Bromly, A. H. Tin mining and smelting at Santa Barbara, Guanajuato, Mexico.

Trans. Amer. Inst. Mg. Eng., Vol. 36, 1906, New York, pp. 227-233, figs. 2.

Mg. Journ. Railw. Comm. Gaz., Vol. 78, 1905, London, pp. 121, 139.

MEXICO (Continued)

Describes deposits and method of producing ore. Ore formation is of an "unusual nature consisting of cracks in the rhyolite which have been filled with clay." These clay stringers carry a mixed mineralization, particularly in the form of iron and tin oxide. Deposits not considered of commercial value.

Data showing results from smelting various classes of ore given. Methods of treatment of the ore are described.

CHANDLER, C. F. On tin ore at Durango in Mexico.

Amer. Journ. Sci. Arts, 2d ser., Vol. 39, 1865, New Haven, p. 349.

The cassiterite is in form of wood-tin and is accompanied by topaz. Gives crucible assay.

COLLINS, J. H. Specimens of tinstones from Durango.

Journ. Roy. Inst. Cornwall, Vol. 13, pt. 1, 1895-1898, Truro, p. 129, about 150 words.

Describes specimens of tin ore from Durango, Mexico.

DEL MAR, ALEX. History of the precious metals.

2d edition, revised. 1902, New York, p. 206.

States Cortes reported that "chisel-shaped" tin money was used in Mexico, and that specimens are in the "Paris collection."

FAWNS, SYDNEY. Tin deposits of the world.

Published by the Mining Journal, 1905, London. Tin deposits of Mexico, pp. 154-157, 1300 words.

Compilation from Ingalls' "Tin deposits of Durango, Mex."; Louis' "Production of tin"; and Nevius' "The Sain Alto tin deposits."

GENTH, F. A. On the occurrence of tin ores in Mexico.

Proc. Amer. Philos. Soc. Vol. 24, 1887, Philadelphia, pp. 23-35.

Description of specimens of tin ore from Sierra de Catalan, State of Durango, Mexico. Small crystals of hematite are replaced by cassiterite. Also mentions wood tin and other forms from various Mexican localities, which contain much iron and arsenic. Quotes from Wm. Semmons, concerning a deposit of SnO_2 upon bismuthinite.

GROSE, JOSEPH. Tin discovery in Mexico.

Mg. Journ. Railw. Comm. Gaz., Vol. 43, 1873, London, p. 863.

Alluvial tin ore washed down from the mountains is found scattered over an area of several square miles, 250 miles southwest of the city of Mexico.

HALSE, ED. The occurrence of tin ore at Sain Alto, Zacatecas, with reference to similar deposits in San Luis Potosi and Durango, Mexico.

Trans. Amer. Inst. Mg. Eng., Vol. 29, 1900, New York, pp. 502-511, figs. 1-6.

Abstract: Eng. Mg. Journ., Vol. 68, 1899, New York, p. 428.

Describes occurrences of tin ore in other localities than Durango, and compares them with the latter. Description of tin smelting at Las Cuevas.

HANKS, HENRY G. On the occurrence of durangite in the tin-bearing region of Durango, Mexico.

Amer. Journ. Sci. Arts, ser. 3, Vol. 12, 1876, New Haven, pp. 274-275.

Description of the tin deposits of Durango. Durangite is found only in the "Barranca" tin mine, eighteen miles northwest from Coneto, State of Durango.

HUMBOLDT, ALEXANDER DE. Essai politique sur le royaume de la Nouvelle-Espagne.

1811, Paris, Vol. 3, pp. 203, 299, 306-307; Vol. 4, pp. 105-106, 194-195.

Extract: Arch. Bergb. Hütt., Vol. 17, 1828, Breslau and Berlin, pp. 358-359.

Extract by A. J. M. Brochant, Notice sur les Mines du Mexique. Journ. Mines, Vol. 30, 1811, Paris, p. 104.

Briefly treats of tin occurrences in Mexico.

MEXICO (Continued)

Tin in veins and alluvial. One tract of over 200 square miles, hastily prospected, shows stream tin in every water course, yielding by washing, from 5 to 20 per cent tin ore. Can be worked by hydraulicking at small cost. Vein tin yields from 60 to 70 per cent metallic tin; very free from injurious impurities. Country granite.

MICHIGAN

785. STEVENS, HORACE J. Tin in Michigan.

Mg. Journ. Railw. Comm. Gaz., Vol. 76, 1904, London, p. 233.

Sketch of desultory attempts at tin mining in United States, with brief mention of recent discoveries of deposits in Keeweenaw County, Michigan.

(These " discoveries " proved false.)

MISSOURI

786. DUNSTAN, R. W. Discovery of tin in Missouri.

Mg. Journ., Railw. Comm. Gaz., Vol. 37, 1867, London, pp. 699, 731.

A letter giving very encouraging outlook for the tin in Missouri, 100 miles south of St. Louis, in a mountainous district of granite, trap and porphyritic rock. States that lodes run nearly north and south. Tin also occurs in alluvial floors, decomposed granite and black sand.

787. GENTH, F. A. Tin ore in the United States.

U. S. Railroad and Mg. Journ., May 4, 1870, Philadelphia.

Reprint: Eng. Mg. Journ., Vol. 9, 1870, New York, p. 322.

Mg. Journ. Railw. Comm. Gaz., Vol. 40, 1870, London, pp. 486-487.

Extract: Ann. Mines, ser. 6, Vol. 17, 1870, Paris, pp. 572-575.

Treats briefly of the tin deposits in the United States. Tells of the pretended discovery of tin in Missouri and the resulting excitement; gives analysis of supposed tin ore sent from Madison County, Mo., and states that traces of tin were found in one specimen; also gives analyses of two concentrates from San Jacinto, Cal.

WHEELER, H. A. *See* No. 1423.

MONTANA

HANKS, H. G. *See* No. 218.

787a. RAYMOND, ROSSITER W. Statistics of mines and mining in the states and territories west of the Rocky Mountains.

Fourth annual report of Rossiter W. Raymond, United States Commissioner of Mining Statistics [for the year 1871], Washington, D. C., 1873, pp. 288-289.

" A Mr. Hall has several bars of tin, weighing a couple of pounds each, reduced by himself from ore picked from the gravel at the adjacent bar [Big Prickly Pear Creek]. The ore is very pure, and similar to the float tin found in Durango, Mexico. Some prospecting has been done for the ledge that this ore is evidently derived from, but so far without success." Entire reference.

NEVADA

788. HOFFMAN, W. J. On the mineralogy of Nevada.

Bull. U. S. Geol. Geogr. Surv. Terr., Vol. 4, 1878, Washington, D. C., p. 734.

The only locality in Nevada where stream tin occurs is at the Tuscarora placer mines where small crystals are occasionally found.

NEWFOUNDLAND

789. MILNE, J. Notes on the physical features and mineralogy of New Foundland.

Quart. Journ. Geol. Soc. London, Vol. 30, 1874, London, p. 745.

States that tin is found in New Foundland, but whether in paying quantities is not yet determined.

NEW GUINEA

790. ANONYMOUS. Tin on Ferguson Island.

Eng. Mg. Journ., Vol. 75, 1903, New York, p. 623.

Rich tin lodes and gravel have been recently discovered on Ferguson Island on the northeast coast of New Guinea. No details given.

NEW HAMPSHIRE

791. JACKSON, CHARLES T. Description of the tin veins of Jackson, N. H.

Report Association American Geologists and Naturalists, 1840-1842 (1843), Boston, pp. 316-321, figs. 2.

Describes the occurrence of small tin-bearing veins near Jackson and the minerals associated with the tin and discusses the origin of the veins.

792. ———. Final report on the geology and mineralogy of the State of New Hampshire, with contributions toward the improvement of agriculture and metallurgy.

1844, Concord, N. H., pp. 139-145, figs. 2.

Review: Amer. Journ. Sci. Arts, ser. 1, Vol. 49, 1845, New Haven, p. 34.

Tin ore at Jackson, N. H. Description of tin veins, crystallization, association. Short translation from Daubrée on description and theory of tin veins. With the tin occurs arsenic pyrites, black sulphuret of copper (rare), carbonate of copper, native copper, tungstate of manganese and iron (rare), black tourmaline and quartz.

NEW JERSEY

793. LESLEY, J. P. The iron manufacturers' guide to the furnaces, forges and rolling mills of the United States, with discussions of iron as a chemical element, an American ore, and a manufactured article in commerce and in history.

1859, New York and London, p. 428.

Trace of tin (.18 per cent SnO_2) found in "garnet rock," about 1½ miles northeast of Andover, New Jersey.

794. SCHNABEL, CARL. Handbook of Metallurgy.

Translated by Louis, Henry, 1898, London, Vol. 2, p. 3.

"Tin has only been found by Eliot and Storer in American zinc from New Jersey, and English zinc made by Vivian & Co., of Swansea."

NEW SOUTH WALES

795. ADAMS, ROBERT. Mining in New South Wales.

Mg. Journ. Railw. Comm. Gaz., Vol. 43, 1873, London, p. 1009.

Working only alluvial deposits. Not more than one-tenth of mines are paying, owing to poor management.

796. A——, R. D. Tin mining in Australia.

Mg. Journ. Railw. Comm. Gaz., Vol. 49, 1879, London, pp. 909-910.

Description of the tin mining at Vegetable Creek, New South Wales.

797. ANDREWS, E. C. The geology of the New England Plateau, with special reference to the granites of northern New England.

Rec. Geol. Surv. New South Wales, pt. 1; Vol. 7, pt. 4, 1904, pp. 281-300, pls. 55-56. Parts 2 and 3, Vol. 8; pt. 2, 1905, pp. 108-152, pl. 20. Parts 4 and 5, Vol. 8, pt. 3, 1907, pp. 196-250, pl. 39.

NEW SOUTH WALES (Continued)

Part 1 describes the physiography; part 2, the general geology; part 3 treats of the genesis of the ore deposits; part 4, of the petrology, and part 5 contains additional notes on the ore deposits.

Permo-carboniferous slates were intruded by granite accompanied by pegmatite, eurite, micrographic dikes and quartz veins and masses. Many of the younger accompanying rocks carry tin, tungsten, and bismuth minerals, molybdenite, monazite, gold and allied minerals. Most of the New England ore deposits are considered to have been formed by magmatic segregations, in which are included those formed from heated gases or waters. The ores are arranged peripherally around acid granite massifs. The Gulf tin deposits occur as pipes formed at the intersection of fissures some of which are of very irregular form. The deposits contain arsenical pyrites, tourmaline, fluorspar, beryl, monazite, bismuth, and wolframite. At Kingsgate, pipes 18 inches to 40 feet in diameter carry molybdenite in masses up to one ton in weight, bismuth, bismuthinite, and bismuth carbonate, and at Tabletop, Timbarra, pipes carry gold in sufficient quantity to pay for working, but at neither place are they tin bearing. The pipes are all formed through replacement of the granite by solutions following very small cracks. At Tingha tin occurs in "a eurite vein," pegmatite and pipes, with chalcedony, and quartz; in the Emerald mines at Emmaville, in quartz veins with white mica, emeralds, and fluorspar cutting carboniferous (?) slates; at Giant's Den, in quartz veins with tourmaline, topaz, and chalcopyrite, cutting greisen; at Pheasant Creek with wolframite, in greisen and "mica rock"; in the Inverell District with abundant topaz, in greisen; at Deepwater with wolframite and iron pyrites in greisen; at Wilson's Downfall with huge quartz crystals and platy wolframite in greisen and granite; at Bald Nob in fissure veins; at Silent Grove in a granular quartz vein with bismuth and galena. At Howell stannite occurs in the Conrad and King Conrad reefs with argentiferous galena and sphalerite.

3. ANONYMOUS. The discovery of tin in New South Wales.
Mg. Journ. Railw. Comm. Gaz., Vol. 42, 1872, London, pp. 45, 398.

). ———. More Australian tin.
Iron, Vol. 5, n. s. 1875, London, p. 551.
A very brief description of some stream tin from foot of Mount Pilot, New South Wales. The region is described geologically.

). ———. Tin in New South Wales.
Min. Ind. for 1900, Vol. 9, 1901, New York and London, pp. 636-637.
Brief epitome of the tin mining conditions in New South Wales.
Tin production of State from 1872 to 1899 inclusive amounted in value to £6,390,484. The lodes have scarcely been touched. Principal lode mine is the Oetery in the Emmaville district.

. ———. Tin in New South Wales.
Min. Ind. for 1901, Vol. 10, 1902, New York and London, p. 639.
Very brief general remarks about tin deposits in New South Wales.

2. ———. Tin and tin mining in New South Wales.
Journ. Soc. Arts, Vol. 50, 1902, London, pp. 285-286.
Brief history of tin discovery in New South Wales; localities and manner of occurrence; production.

. ———. Tin in New South Wales.
Journ. Franklin Inst., Vol. 161, 1906, Philadelphia, p. 384.
A note. "At Tingha, Inverell district, there are fifteen or sixteen dredges working for tin, all doing well. Reported that they have work for six to ten years ahead of them."

NEW SOUTH WALES (Continued)

804. ———. Beach mining in New South Wales.

Queensland, Gov. Mg. Journ., Vol. 8, 1907, Brisbane, p. 175.

Refers to report on beach mining in Queensland, made by L. C. Ball in 1905, and states that under similar conditions to those he described a French company intends to work the 13 miles of beach, from one mile south of Evans or Little River, at the mouth of Richmond River, running northerly to McAuley's Lead. "The sands are said to contain gold, platinum, tin, monazite, and other minerals," but the richness is not known.

805. ———. Beach mining in New South Wales.

Queensland Gov. Mg. Journ., Vol. 8, 1907, Brisbane, p. 275.

The Byron Bay correspondent of the "Town & Country Journal," under date 8th May, writes: A new mining plant has been set up at Broken Head, on the northern end of Seven-mile Beach, that was formerly very rich in gold, tin and platinum. A Sydney syndicate has just completed a plant, to treat the black sands for six or more kinds of minerals, which have a good market value. All previous work along this foreshore was confined to the recovery of gold and tin. It has now been found that minerals of equal value exist in the concentrates. Other parties are also working the beach sands.

806. Beer, Adolf. Geschichte des Welthandels.

1864, Vienna, pp. 210-211.

Short notice of the tin production in New South Wales and Queensland.

807. Benedict, Wm. De L. Tin in New South Wales.

Min. Ind. for 1892, Vol. 1, 1893, New York, p. 443.

Principal alluvial deposits in New South Wales are situated about 400 miles north of Sydney, on western slope of the great dividing range. Alluvial deposits said to be practically exhausted. Tin has been found in veins in the Emmaville district, the principal one being the Oetery mine.

Brown, A. Selwyn. *See* Nos. 1307 and 1308.

808. Card, George W. Minerals of economic value, New South Wales (tin).

Handbook to the Mining and Geological Museum, Sydney, 1902, Sydney, pp. 65-67, 113-115.

General description of tin ore and its manner of occurrence, with a list of specimens in the museum at Sydney.

809. Carne, J. E. The auriferous beach sands of the Esk River and Jerusalem Creek, in the parish of Esk County, Richmond, New South Wales.

Rec. Geol. Surv. New South Wales., Vol. 5, 1898, Sydney, pp. 71-86.

A number of assays of the sands are given, nearly all showing presence of tin. possible sources of the gold, platinum and tinstone in the sands are:

(1) The underlying Siluro-Devonian rocks which contain poor quartz reefs.
(2) The Clarence coal measures.
(3) Drifts under basalt, known to occur and to be slightly auriferous.
(4) The basalt, doubtfully gold bearing.
(5) The draining channels from New England.

810. Clarke, W. B. Leading article on mining containing a prognostication of the discovery of tin in New South Wales.

April 16, 1849, Sydney Morning Herald.

Not available to the authors.

NEW SOUTH WALES (Continued)

———. Mines and mineral statistics of New South Wales.

May 7, 1853, p. 71.

In author's report to the Colonial Secretary, he drew attention for the first time to the probable occurrence of extensive deposits of tin ore. He then stated that "wolfram and oxide of tin with tourmaline, occur near Dundee and in Paradise Creek, and it is probable that this ore of tin is plentifully distributed in the alluvial of other tracts as I have found it amidst the spinelle, rubies, oriental emeralds, sapphires, and other gems of the detritus from granite."

———. Researches in the Southern gold fields of New South Wales, 1860.

Tin, pp. 109, 128.

———. Anniversary Address.

Trans. Proc. Roy. Soc. New South Wales, for 1873 (1874), Sydney, pp. 1-39.
Address contains notes on tin in New South Wales.

———. Remarks on the sedimentary formations of New South Wales, etc.

Edition 3, 1875, Sydney, pp. 61, vertical sections.
Digest: Geol. Rec. for 1875, London, p. 148.
Tin mines of New South Wales and Queensland occur in Devonian rocks.

COGLAN, T. A. The wealth and progress of New South Wales for 1886-1887.

Sydney, 1887, pp. 82-84. Ibid., for 1890-1891 (1891), pp. 84-86. Ibid., for 1894 (1896), pp. 210-212. Ibid., for 1895-1896, Vol. 2, 1897, pp. 493-1023.

CONDER, HARTWELL. The occurrence of stannite in Australasia.

Austr. Mg. Stand., Vol. 40, 1908, Sydney and Melbourne, p. 577.

Gives a description of stannite and mentions localities in which it has been found. States that it occurs in considerable quantity in the Conrad mines, New South Wales, and the Oonah Mine (Zeehan) and at Heemskirk, Tasmania. In the Conrad mine stannite occurs in a quartz vein cutting granite and is accompanied by argentiferous galena, zinc blende, chalcopyrite and arsenical pyrites. Cassiterite occurs in the granite, but rarely if ever in the vein. At Oonah stannite occurs with bismuthinite, wolframite, galena, pyrite, and zinc blende in a vein between quartzite and graphitic schist, and closely connected with galena deposits. Stannite at both places is argentiferous. Discusses difficulties of treatment.

COTTON, LEO A. The tin deposits of New England, New South Wales.

Part 1, Proc. Linn. Soc. New South Wales, Vol. 34, 1910, Sydney, pp. 733-781, pls. 59-62, figs. 13, geol. map.

Describes the country rocks in detail, the distribution of the lodes, their direction and causes of trend. The deposits are divided into eleven classes which do not appear to be very distinctive. The veins under the different classes are described and comparisons made with occurrences in other countries.

COX, HERBERT S. Tin deposits of New South Wales.

Journ. Proc. Roy. Soc. New South Wales, for 1886, Vol. 20, 1887, Sydney, pp. 93-112, figs. 7.

General description of both lode and alluvial deposits with geology of district. Accompanying minerals are wolframite, copper pyrites, arsenical pyrites, fluorspar (not in large quantities), tourmaline, fluorine bearing micas, and topaz; at Gulf mine, near Bendemeer, beryl forms a rock in which cassiterite is impregnated. In the Inverell district, diamonds, sapphires and zircons occur with stream tin. Cassiterite is iridescent at Silverton.

NEW SOUTH WALES (Continued)

DAVIES, D. C. *See* No. 1317.

818. DAVID, T. W. Edgeworth. Geology of the Vegetable Creek tin-mining field, New England District, New South Wales.

Dep. Mines Geol. Surv., New South Wales, No. 1, 1887, Sydney, pp. x and 169, figs. 12, and map.

Review: Amer. Geol., Vol. 1, 1888, Minneapolis, p. 122.

Gives a history of tin-mining in New South Wales; physiography, meteorology; geology; mineralogy, etc. Much of the country is covered by basalt up to 200 feet thick, averaging 200 feet. In places, stanniferous stream gravels covered by the basalt have to be crushed before the tin can be obtained.

Siluro-Devonian sediments are intruded by quartz felsite dikes and granite, probably of Permian age. The tin deposits are associated with this granite. The stanniferous gravels both exposed and lava-covered are described in detail. Some of the stream tin is only 1/70 of an inch in diameter but shows sharp crystal edges. Sapphire, topaz, zircon, spinel, garnet, magnetite and ilmenite are found in the placers. Gold is also found in small quantities.

Ninety veins and stockworks are described.

Quartz is found in 69 veins; chlorite in 29; feldspar in 20; mica and arsenopyrite each in 8; pyrite and fluorspar, each in 4; tourmaline and wolframite, each in 3; zinc blende, galena, chalcopyrite, bismuth, molybdenite, vesuvianite and stilbite, each in 2; hematite, pyrrhotite, manganese, scheelite and beryl, each in one vein.

The veins range up to 3 feet in thickness.

Gold, silver, lead and copper occur in veins of the neighborhood. Silver is in commercial quantity.

819. DEPARTMENT of Mines, New South Wales, Annual Reports from 1875.

Sydney.

Since 1875, the Department of Mines of New South Wales has issued annual reports upon mines and minerals of the State, with the statistics of production and progress of the industry as shown by reports from the wardens of the various districts, mine inspectors and geologists.

FAWNS, SYDNEY. *See* No. 1320.

820. GENTH, F. A. Contributions to mineralogy.

Proc. Amer. Philos. Soc. Vol. 23, 1886, Philadelphia, pp. 30-31.

Treats of some specimens of tin ore and their associated minerals from Aberfoil and Sam rivers, New South Wales.

821. GOWER, GEORGE H. Report on the Vegetable Creek tin field.

Ann. Rep. Dep. Min. New South Wales, for 1874, Sydney, pp. 63-70. (With plan of the dressing machinery designed by W. H. Wesley.)

822. ———. New England and Clarence district. Vegetable Creek division.

Ann. Rep. Dep. Mines New South Wales for 1876 (1877), Sydney, pp. 110-114, pls. 2.

Giving progress of each mine of the district with total yield from 1872-1876; also a description of new machinery used for washing gravel for tin.

823. ———. Report on the New England and Clarence Mining District.

Ann. Rep. Dep. Min. New South Wales, for 1878, Sydney, pp. 126-130 (with a sketch plan of the Vegetable Creek mining district, showing the approximate position of the creeks, and the localities of the principal mines working for stream tin under basaltic formation, and of the tin lodes. Scale: 4 miles to 1 inch).

NEW SOUTH WALES (Continued)

———. Report on the condition and prospects of the Vegetable Creek tin mining district for the year 1879.

Ann. Rep. Dep. Min. New South Wales for 1879 (1880), Sydney, pp. 149-156. (With plan and section of Messrs. Wesley Bros. workings, two plans of machinery, and a table showing total yield of tin ore from the Vegetable Creek tin mining district.)

JAQUET, J. B. Tin bearing dykes (?) of Euriowie and Waukeroo.

Geol. of the Broken Hill Lode and Barrier Ranges Mineral Fields, New South Wales, Mem. Geol. No. 5, 1894, Sydney, pp. 128-131, pl. 1.

After general description of the ore and accompanying rocks, the following subjects are treated:

Analogous occurrence of tin in Dakota; Huel Byjerkerno mine; Mount Euriowie mine; Badjerican mine; Calorla (Euriowie Tin-mining Co.); Barrier Bischoff mine; Thistle mine.

KJERULF, TH., and BRÖGGER, W. C. Zinnsteinvorkommniss aus New South Wales.

Neues Jahrb. Min., 1879, Stuttgart, pp. 566-567.

LIVERSIDGE, A(RCHIBALD). The minerals of New South Wales.

Trans. Proc. Roy. Soc. New South Wales, Vol. 9, 1876, Sydney, pp. 177-179.

Description of tinstone; its occurrence in veins and alluvial deposits, and the localities where found.

———. Minerals of New South Wales.

1st edition, 1876, Sydney, pp. 25-27. 2d edition, 1882, Sydney, pp. 39-41. 3d edition, 1888, Sydney, pp. 76-84.

Treats of: Tin (chemical composition, appearance, specific gravity of ores); tin deposits; localities.

———. Map of the minerals of New South Wales.

1888, Sydney, pp. 3-32. Min. map.

An alphabetical list of mineral localities, including the tin deposits of the state.

———. On some New South Wales and other minerals.

Journ. Proc. Roy. Soc. New South Wales, Vol. 29, 1895, Sydney, pp. 323-324.

Analyses of some cassiterite crystals from Elsmore mine, Inverell, New South Wales.

LOUIS, HENRY. *See* No. 1340.

MINGAYE, JOHN C. H. Notes on the occurrence of platinum, gold and tin in the beach sands in the Richmond River district, New South Wales.

Journ. Proc. Roy. Soc. New South Wales, Vol. 26, 1892, Sydney, pp. 368-370.

Sand from the Richmond River district was examined and a few of the results obtained given. Tin was present in all the samples, but percentage was not determined in every case.

NEWLAND, D. H. Tin in New South Wales.

Min. Ind. for 1902, Vol. 11, 1903, New York and London, p. 593, 250 words.

Gives the tin output of New South Wales during 1902 and reviews conditions of mining.

———. Tin in New South Wales.

Min. Ind. for 1903, Vol. 12, 1904, New York and London, pp. 327-328.

Gives the tin output of New South Wales during 1903 and notes that there was a marked increase in the use of dredges, the recovery by this means amounting to 244 long tons. Considerable abandoned ground has been worked profitably, owing to the increased price obtained for tin and to improved methods.

NEW SOUTH WALES (Continued)

PHILLIPS, J. A., and LOUIS, H. *See* No. 1350.

834. PITTMAN, E(DWARD) F. Tin deposits of New South Wales.
Published by the Government, giving a full description of the mines and methods of working. 1899.
Not available to the authors.

835. ———. The mineral resources of New South Wales.
Geol. Surv. New South Wales, 1901, Sydney, pp. 130-150, pls. 3, figs. 4.
Tin: History of development, occurrence and places where mined.
Largely a digest of T. W. E. Davids' "Geology of the Vegetable Creek Tin-mining Field."

836. PLUMMER, JOHN. Tin mining in New South Wales.
Eng. Mg. Journ., Vol. 73, 1902, New York, p. 212.
General description of tin deposits of New South Wales and a more detailed account of Vegetable Creek tin field, the leading one of the State.

837. ———. Mining in New South Wales.
Mg. Journ. Railw. Comm. Gaz., Vol. 76, 1904, London, p. 375.
Dredgers for tin not properly equipped for saving tin ore.

838. REID, G. H. An essay on New South Wales, the mother colony of the Australias.
1876, Sydney, pp. 72-73.
A very brief sketch of the tin industry at that date. Tin production from 1872-1875 given.

REYER, EDUARD. *See* No. 1354.

839. SLEE, W. H. J. Mineral deposits, etc., in New South Wales.
Report of Mining Conference, New South Wales, 1896, p. 6.
Not available to the authors.

840. STEPHEN, G. MILNER. Discovery of tin in New South Wales.
Mg. Journ. Railw. Comm. Gaz., Vol. 42, 1872, London, pp. 45, 398.
Also, Quart. Journ. Geol. Soc. London, Vol. 28, 1872, London, p. 42.
Announcement by letter of great deposit of tin ore in district of New England. The tin ore is said to be in "pepitas crystals, and beds of conglomerate, especially in micaceous granite more or less decomposed."

STOKES, RALPH S. G. *See* No. 730.

841. STONIER, G. A. Report on tin-bearing country in the county of Bourke.
Mg. Journ. Railw. Comm. Gaz., for 1889 [1890], London, pp. 234-235.

842. TAYLOR, N. Report on the property of the Pheasant Creek tin syndicate, New England.
New South Wales Leg. Ass. Papers, 1883-1884, 796-A, pp. 20-21.
Not available to the authors.

843. THIBAULT, P. J. Tin mining in New South Wales.
Austr. Mg. Stand., Vol. 33, 1905, Sydney and Melbourne, pp. 444-445, 465-466. Serial "A summary review covering the period from 1900 to 1904 inclusive."

844. ———. Tingha tin dredging industry, New South Wales.
Austr. Mg. Stand., Vol. 38, 1907, Sydney and Melbourne, pp. 128, 148-149, 174-175, 197-198, 222-223, 246-247, 265-266, 292. Illustrated.

NEW SOUTH WALES (Continued)

Gives methods of dredging and results obtained by following companies: Melbourne Cope's Creek Tin Sluicing Co., Tingha Consolidated Tin Mines, Elsmore Tin Sluicing Co., The Tingha Tin Dredging Co., Cope's Creek Central Tin Dredging Co., The Amalgamated Tin Dredging Co., Cope's Creek Dredging Co.

———. *See* No. 1644.

4a. TRENCHARD, H. G. Recovery of tin from alluvial deposits.

Austr. Mg. Stand., Vol. 41, 1909, Sydney and Melbourne, pp. 37-38.

"Notes on the stream sluicing plants at Tingha, New South Wales, for recovering tin from the abandoned workings and leads too poor for hand treatment."

5. ULRICH, G. H. F. Observations on some of the recent tin ore discoveries in New England, New South Wales.

Quart. Journ. Geol. Soc. London, Vol. 29, 1873, London, pp. 5-11, figs. 2.

Abstracts: Mg. Journ. Railw. Comm. Gaz., Vol. 42, 1872, London, p. 1105; Geol. Mag., Vol. 9, 1872, London, pp. 569-571.

District described is in northern part of colony of New South Wales, almost immediately adjoining tin region of Queensland.

6. Changed to 578a.

7a. WILKINSON, C. S. Report on the discovery of tin and other metals in the Burra Burra district, between the Bogan and Lochan rivers.

Queenslander, Vol. 12, 1876.

Not available to the authors.

7b. ———. Report on tin bearing country, New England.

New South Wales Leg. Ass. Papers, 1872, 181-A (Folio, Sydney, 1873. By authority), p. 10, pls.

Not available to the authors.

7c. ———. Report on tin bearing country, district of Inverell.

Enclosing Rev. W. B. Clarke's report on Geological Surveys, May 7, 1853, pp. 11, New South Wales Leg. Ass. Papers, 1872-1873, 176-A (Folio, Sydney, 1873. By authority).

Not available to the authors.

7d. ———. Tin deposits of New South Wales.

Iron, Vol. 3, 1874, London, pp. 267, 296, 325.

7e. ———. Tin deposits of New South Wales.

Mg. Journ. Railw. Comm. Gaz., Vol. 44, 1874, London, p. 200.

7f. ———. Report of Progress (Vegetable Creek tin fields).

Ann. Rep. Dept. Min. New South Wales for 1883 [1884], Sydney, pp. 148-152.

7g. ———. Report on mineral reserves, Molong district. (Gumble tin lodes.)

Ann. Rep. Dept. Mines New South Wales, for 1886 [1887], Sydney, p. 132.

7h. ———. Report on tin lodes near Poolamacca, in the Silverton district, New South Wales.

Ann. Rep. Dept. Mines New South Wales, for 1887 [1888], Sydney, pp. 141-144.

8. ———. Report on the Mount Euriowie tin properties, New South Wales, 1887.

Not available to the authors.

NEW SOUTH WALES (Continued)

849. WILKINSON, C. S., and DAVID, T. W. E. Geological map showing the principal stanniferous leads in the Tingha and Elsmore districts, 1895. Scale, 80 chains to 1 in.

Not available to the authors.

850. WOOD, HARRIE M. Tin.

Min. Products of New South Wales, 1882, Sydney, p. 27, Ibid., 1887, p. 34.

Brief very general articles upon the occurrence and production of tin in New South Wales.

NEW ZEALAND

851. ANONYMOUS. Tin on Stewart Island (N. Z.).

Austr. Mg. Stand., Vol. 18, 1900, Sydney and Melbourne, p. 310.

A note stating that tin exists on Stewart Island in vein and alluvial deposits. The latter are worked in a small way at Half Moon Bay. The deposits are not extensive.

852. BELL, JAMES M. The salient features of the economic geology of New Zealand.

Econ. Geol., Vol. 1, 1906, Lancaster, p. 750.

"Cassiterite has been found in the form of 'stream tin' in some of the streams amid the rugged hills of Stewart Island, and has been reported to occur actually in granite." Whole Reference.

853. BINNS, GEORGE J. Mining in New Zealand.

Trans. Fed. Inst. Mg. Eng., Vol. 4, 1892-1893, Newcastle-upon-Tyne and London, p. 67.

Tin ore has been known for some years in auriferous conglomerates at the base of the coal measures at Lankey's Creek, Reefton, Milford and Dusky sounds on the west coast of Otago. In 1888 tin ore was found in gravels, and *in situ* "associated with gneissic granitoid rocks" in the Remarkable Mountains, Stewart Island. Deposits small, climate wet. In April, 1892, stream tin was found in the gold wash at Humphrey's Gulley, near Hokitika, on the west coast of the South Island.

FAWNS, SYDNEY. *See* No. 1320.

854. LAUNAY, L. DE. Les richesses minérales de la Nouvelle-Zélande.

Ann. Mines, ser. 9, Vol. 5, 1894, Paris, pp. 549-550.

855. MCKAY, ALEXANDER. On the geology of Stewart Island and the tin deposits of Port Pegasus district.

Reports of Geological Explorations during 1888-89, New Zealand Geological Survey, Publication No. 20, Wellington, 1890, pp. 74-85. Sketch map of tin fields of Pegasus Dist., figs. 6.

Stream tin was found in shallow gravels with gold, but was not rich enough to work except with the gold. It averaged less than 1 ounce of stream tin to the "tin-dishful" (*sic*). In the Tin Range on Port Pegasus tin occurs in "quartz rock" 6 inches to 1 foot thick, with "mica rock" above and below. More wolframite than cassiterite is carried by the "quartz rock." Granular topaz, gahnite, sphalerite with "blue faces," and pyrites, accompany the cassiterite.

NIGERIA

856. ANONYMOUS. Alluvial tinstone deposits of Northern Nigeria.

Bull. Imp. Inst. Great Britain, Vol. 5, No. 2, 1907, London, pp. 179-183.

Extract: Mg. World, Vol. 27, 1907, Chicago, p. 562.

Description of alluvial tin deposits along the River Delime, tributary to Lake Tchad, 220 miles northeast of Lokoja. In highest land of Northern Nigeria. Country

NIGERIA (Continued)

rock is gneiss cut by basalt, dolerite and pegmatite dikes. No tin ore is found in place. Metallic tin reported as native, is always near native furnaces. An analysis of a specimen of stream tin is given showing about 67 per cent SnO_2. Ilmenite and some monazite and zircon occur with the stream tin.

Gives an account of the native method of working stream tin. The Niger Co. in 1905 produced one ton of "black tin" per day.

7. DUNSTAN, WYNDHAM R. Tin ore from the Bautshi tin fields, Northern Nigeria.

Imp. Inst. Tech. Rep. and Sci. Papers, London, 1903, p. 53. Same, Bull. Imp. Inst. Great Britain, Vol. 1, 1903, London, p. 21.

Chemical examination of a tin specimen weighing 1 pound which came from a depth of 6 feet from the surface of a plain lying to the north of a range of hills about 70 miles southwest of Bautshi in Northern Nigeria. Analysis showed 81.30 per cent tin dioxide. Extent of deposit not known.

8. ———. Report on a series of mineral and vegetable products from Northern Nigeria.

Colonial Reports (Miscellaneous), No. 26, 1904, London, pp. 17-18.

Tin ore from the Tilde area about 15 miles southwest of Badika, also gravel carrying tin, from the River Gimpu, three miles west of Tilde, are analyzed and described.

9. ———. Reports on the mineral survey of Southern Nigeria for 1903-1904 and 1904-1905.

Colonial Reports (Miscellaneous), No. 33, 1906, London, pp. 22-29.

Extract: Mg. Journ. Railw. Comm. Gaz., Vol. 78, 1906, London, p. 546.

Digest: Eng. Mg. Journ., Vol. 81, 1906, New York, p. 992.

Describes alluvial tin occurences of Uwet and Akwa-Ibama districts. Only the latter contained tin deposits rich enough to warrant working, but these are described as poor in comparison with other alluvial deposits. Associated with columbite, garnet, ilmenite and tourmaline, with a small amount of quartz and occasionally magnetite. Conclusions drawn from examination are not of a definite character.

10. NICOLAUS, R. C. Tin deposits of Northern Nigeria. In tin deposits of the world, by Sydney Fawns.

1905, London, pp. 139-141. Written Dec. 1904.

Found in the Naraguta and Shere Hills, outliers of the Gura Mountains in the Badiko district, Province of Bauchi, 600 miles northeast of Lokoja, situated at the confluence of the Niger and Benue rivers. Occurs as coarse and fine stream tin along the Gimpy or Kogin-Delume ("river tin"). Hills of granite with intrusions of diabase and porphyry. Near river is a contact with coarse gray gneiss. Tin thought to come from stockworks in granite. Metallic tin in nodules about the size of a bean, thinly coated with SnO_2, is found 15 feet below the surface of the gravels. Gravels said to average 36.66 pounds stream tin per ton. Smelted with charcoal in small local furnaces. The product is 99.40 tin.

NORTH AMERICA

See under Canada, Greenland, Mexico, Santo Domingo, United States and separate States.

NORTHERN TERRITORY

1. ANONYMOUS. Tin at Port Darwin, Northern Territory, Australia.

Mg. Sci. Press, Vol. 89, 1904, San Francisco, p. 273.

A shipment of tin ore from Port Darwin is said to have carried 75 per cent tin and worth about £80 per ton, it is said this was taken from an area of ground not covering 25 yards (square), depth 4 feet. Open cut work; is below an outcrop of quartz thickly studded with tin ore.

NORTHERN TERRITORY (Continued)

861a. PLAYFORD, E. C. Tin in Australia.

Mg. Journ. Railw. Comm. Gaz., Vol. 85, 1909, London, p. 577.

Notice of same. Eng. Min. Journ., Vol. 87, 1900, New York, p. 1272.

Gives an account of, and outlook for a new discovery of alluvial tin at a place bearing the native name of Warra, close to Pine Creek, Northern Territory.

Tin ore is black, with a little brown, ruby, amber and wood tin. Country rock consists of a gray granite and sandstone, with a little quartz. Small amount of monazite has been found with tin.

862. TATE, RALPH. Report on the Northern Territory.

Geol. Surv. South Australia, No. 63, 1882, Adelaide, p. 4, map.

Two alluvial deposits have been located, along one of the tributaries of McKinlay River, and the head waters of a stream near Mt. Wells. The deposits are of comparatively little importance. Neither of these deposits of tinstone seemed to be associated with granite.

863. TENISON-WOOD, J. E. Report on the geology and mineralogy of Northern Territory.

Geol. Surv. South Australia, No. 122, 1886, Adelaide, p. 7.

Ore occurs in the form of reef tin. Is abundant and rich. Spread over wide area. Metalliferous country resembles that of Cornwall. "The Northern Territory may be emphatically pronounced to be a tin country."

NORWAY

BRÖGGER, W. C. *See* No. 1596.

PERAK

See Malay Peninsula

PERSIA

864. HENNECKE, LUDWIG. Die Bodenschätze Persiens.

Zeitschr. Berg. Hütt. Sal. preuss. Sta., Vol. 47, 1899, Berlin, pp. 272-274.

Digest trans: Trans. Inst. Mg. Eng., Vol. 18, 1899-1900, London and Newcastle-upon-Tyne, p. 509.

"Rich occurrences have been certified in many parts of Persia, of mercury, copper, tin, and antimony-ores, realgar, native sulphur, brown iron ore, manganese and cobalt-ores, kaolin, borax and alum."

865. MACTEAR, JAS. Some notes on Persian mining and metallurgy.

Trans. Inst. Mg. Met., Vol. 3, 1894-95, London, pp. 2-3.

Quotes from a letter of Dr. Riach to Lord Palmerston in 1837 concerning [illegible] supposedly very large deposit of tin ore on Anngert Creek near the village of Juw[illegible] 60 miles northeast of Tabriz, but when visited in 1893 or 1894 by Mactear, nothing was known of the tin.

PERU

866. ANONYMOUS. Nuevos yacimientos de estaño y bismuto en el Perú.

Bol. Soc. Nac. Min., No. 87, 1905, Lima, pp. 103-105.

Extract: Mo. Bull. Int. Bur. Amer. Repub., Vol. 21, July, 1905, Washington, D. C., p. 131.

Until recently tin ores were considered rare in Peru, the only deposits known to exist being those described by Prof. Raimondi in the district of Moho, Province of Huancané, Dept. of Puno. Mineral veins and veinlets containing tin were afterwards described by Carlos Posth as existing in quartz in the Pataoca and Accaobina spurs in of the Andes in the Vilque district. Tin is now known to be widely distributed Peru. Some specimens from Province of Cajatambo, were rich in metallic tin.

PERU (Continued)

67. LARROUY, —. L'industrie minière au Pérou en 1900.
Ann. Mines, ser. 9, Vol. 20, 1901, Paris, p. 510. Extract of report by author.
Tin ore is rare in Peru and no veins that would pay for working have been found; there is however, a vein of no importance at Huancane, Puno.

68. Changed to 171a.

69. POSTH, C. Estado actual de la mineria en el Depto. de Puno.
Bol. Min. Indust. Constr., Ano 10, No. 8, 1894, Lima, p. 63.
Notes the finding of stanniferous quartz veins in the Pataoca and Accoabina Mountains. Vilque district, Puno Department.

70. RAIMONDI, A. Minerales del Perú.
1878, Lima, pp. 168-170.
A French translation was made by Martinet, J. B. H., "Minéraux du Pérou." 1878, Paris, pp. 187-189.
Digest: Zeitschr. Kryst. Min., Vol. 6, 1882, Leipzig, p. 632.
Amorphous cassiterite is found in small quantities in Moho district, Huancané province. Describes a new mineral plumbostannite, a sulphide of lead, tin and antimony, discovered in same district. Occurs with zinc blende and quartz.

PHILIPPINE ISLANDS

71. MCCASKEY, H. D. Stream tin in Negros.
Philippine Min. Ind., a separate from Min. Res. of the United States, 1905, Washington, D. C., pp. 12-13.
Reported that "large tin deposits of stream tin occur in Negros" but no details are given. [This report was later found to be erroneous.—Authors.]

PORTUGAL

72. ANONYMOUS. Tin mines in Sandinha, Portugal.
Mg. Journ. Railw. Comm. Gaz., Vol. 80, 1906, London, p. 495.
Brief note. Mines situated near Goes. Deposits included in old Cambrian schists, near granite. Quartz veins are impregnated with cassiterite and small quantities of pyrite and mispickel.

———. *See* No. 1027.

BECK, RICHARD. *See* No. 1299.

73. BREIDENBACH, TH. Die Zinnerzlagerstätten Portugals.
Glück. Berg. hütt. Zeit. Nied. Westph., 1893, Essen, pp. 1032, 1050.
Digest: Neues Jahrb. Min., 1894, II (Ref.), Stuttgart, pp. 429-430.

BROWN, A. SELWYN. *See* Nos. 1307 and 1308.

CALDERÓN, D. SALVADOR. *See* No. 1029.

D'ACHIARDI, ANTONIO. *See* No. 1313.

74. ESCHWEGE, W. VON. Bemerkungen über den Bergbau und Hüttenbetrieb in Portugal.
Arch. Miner. Geogn. Bergb. Hütt., Vol. 8, 1835, Berlin, pp. 221-222, 224.

FAWNS, SYDNEY. *See* No. 1320.

FUCHS, E., and LAUNAY, L. DE. *See* No. 1323.

PORTUGAL (Continued)

875. HEALE, JOSH. Tin in Portugal.
Mg. Journ. Railw. Comm. Gaz., Vol. 44, 1874, London, p. 343.
Report on the tin mines of São Martinho and Montesinhos in the Province of Tras os Montes.

LOUIS, HENRY. *See* No. 1340.

PHILLIPS, J. A., and LOUIS, HENRY. *See* No. 1350.

QUEENSLAND

876. ANONYMOUS. Vulcan tin mine, Irvinebank, Queensland.
Austr. Mg. Stand., Vol. 11, 1895, Sydney and Melbourne, p. 524.
Digest: Trans. Fed. Inst. Mg. Eng., Vol. 10, 1895, Newcastle-upon-Tyne and London, p. 590.
Describes the Vulcan mine and states that it is the most productive tin mine in North Queensland.

877. ———. Mining in Queensland (gold, silver, tin, copper, coal and other minerals).
The Queenslander, Vol. 51, March 27, 1897, Brisbane, p. 2.
Not available to the authors.

878. ———. Tin in Queensland.
Min. Ind. for 1900, Vol. 9, 1901, New York and London, p. 637.
A short general review of conditions in the tin fields of Queensland during 1900.

879. ———. Tin in Queensland.
Min. Ind. for 1901, Vol. 10, 1902, New York and London, pp. 639-640.
Brief review of tin mining conditions during 1901.

880. ———. Queensland tin mining.
Austr. Mg. Stand., Vol. 30, 1903, Sydney and Melbourne, p. 801.
Particulars of a new find of rich tin ore in the neighborhood of Reid's Cr— Queensland, taken from "Wild River Times," Q.

881. ———. Tin mining in north Queensland.
Mg. Journ. Railw. Comm. Gaz., Vol. 75, 1904, London, p. 602.
Outlook for tin in Herberton district very encouraging. The Lancelot lode, Silver Valley, 10 miles southwest of Herberton, has an average width of 2 feet, has been exploited to a depth of 250 feet. Average per cent of tin in the ore is f— 12 to 13 per cent. Concentrates contain 60 per cent metallic tin, 5 per cent bism— and 5 per cent copper. Outputs from 1899 to 1903 of New South Wales and Que— land given.

882. ———. Tin mining in Queensland.
Mg. Journ. Railw. Comm. Gaz., Vol. 76, 1904, London, p. 113.
Gives present conditions in tin mining and the production in the Herberton dist—

883. ———. Dredging for tin at Stanthorpe.
Queensland Gov. Mg. Journ., March 15, 1904, Brisbane, p. 103.
"Shows Brisbane dredging plant."
Not available to the authors.

884. ———. Queensland tin supply.
Austr. Mg. Stand., Vol. 31, 1904, Sydney and Melbourne, p. 809.
"Information concerning the output, which shows a marked increase."

QUEENSLAND (Continued)

——. The Vulcan tin mine, North Queensland.

Eng. Mg. Journ., Vol. 82, 1906, New York, p. 155.

Vulcan mine, Herberton district, North Queensland, has recently developed into one of the most important lode tin mines of the world. It surpasses, as producer and dividend payer, even the famous Mt. Bischoff mine. During 1905, production was at the rate of 130 tons of black tin per month. Description of mine is from report by Walter E. Cameron, Asst. Geol. of the Queensland mines department.

ABINGTON, ARTHUR. Herberton tin field.

Austr. Mg. Stand., Vol. 16, 1899, Sydney and Melbourne, pp. 88-89, 129.

"Information concerning these deposits in North Queensland, and their workings."

AIN, W. H. The Tate tin mines.

Austr. Mg. Stand., May 28, 1896, Sydney and Melbourne.

"Description of the largest and most important of the stream tin mining properties now being worked in North Queensland."

Not available to the authors.

ALL, LIONEL C. Crow's Nest tin deposits.

Queensland Gov. Mg. Journ., Oct. 15, 1903, Brisbane.

"Report on the geology and workings of tin deposits in Queensland."

Not available to the authors.

——. Notes on tin, copper and silver in the Stanthorpe District.

Geol. Surv. Queensland, Pub. 191, 1904, Brisbane, pp. 9-21, pls. 1-8, plan and elevation 1.

Also, Queensland Gov. Mg. Journ., July 15, 1904, 1st part. Brisbane.

Notes on tin mining in the Stanthorpe district treat of pan-washing and cradling; ground sluicing; dredgers, and lode tin mining.

——. Progress Report, 1904.

Ann. Rep. Under-Secretary for Mines, Queensland, for the year 1904 (1905), Brisbane, pp. 155.

"On the 7th January, I left Brisbane to investigate a discovery of tinstone on Brovina Creek, in the Gayndah district. Small quantities of the mineral were found to occur in one branch of the creek, but the prospects were not encouraging, and it is believed that work has now ceased." (Whole reference.)

——. Gold, platinum, tinstone and monazite in the beach sands on the South Coast (Queensland).

Geol. Surv. Rep., Queensland, Pub. No. 198, 1905, Brisbane, pp. 1-19, figs., pls. 1, 2.

"At intervals along the Currumbin-Coolangatta Beach, the sands contain payable tin, accompanied by gold. The concentrates, however, assay very much lower than was expected, and the assays show that the work thus far done for tin has been at a loss, either owing to local poverty of the ground or to the escape of tinstone with the tailings. Nevertheless, the hope is entertained that the ground may yet be proved sufficiently rich for dredging."

——. King of the Ranges tin mine, Watsonville, N. Q.

Queensland Gov. Mg. Journ., Vol. 10, 1909, Brisbane, pp. 228-232, illus.

——. Irvinebank Company's treatment works.

Queensland Gov. Mg. Journ., Vol. 10, 1909, Brisbane, pp. 329-330, illus.

Description of methods used for crushing, concentrating and smelting of tin ores at Irvinebank.

EER, ADOLF. *See* No. 806.

ROWN, A. SELWYN. *See* Nos. 1307 and 1308.

QUEENSLAND (Continued)

892. CAMERON W(ALTER) E. Report on the Stannary Hills tin deposits.

Queensland Gov. Mg. Journ., Vol. 1, 1900, Brisbane, pp. 190-191.
Not available to the authors.

893. ———. Report on the Kangaroo Hills mineral fields, Queensland.

Geol. Surv. Rep. Queensland, Pub. No. 167, 1901, Brisbane, pp. 1-11, pls. 8, geol. map 1.

894. ———. Report on the Cardigan (Queensland) Tin-Syndicate's Properties, Thompson's Creek, and the Coolgarra Federal Corporation Limited, Leases, Herberton Mineral District, North Queensland.

Geol. Surv. Rep. Queensland, Pub., No. 165, 1901, Brisbane, pp. 1-4.
"The above syndicate has acquired a number of abandoned tin properties formerly worked for tin by the prospectors of the Herberton field. The object of this syndicate is to develop and work these leases in a more systematic manner than was possible with the methods available to small parties of working miners."
Each piece of leased property is described.

895. ———. The Herberton tin field.

Geol. Surv. Rep. Queensland, Pub. No. 192, 1904, Brisbane, pp. 1-29, pl. 1 (geol. map.)
Digest: Mg. Journ. Railw. Comm. Gaz., Vol. 76, 1904, London, p. 359.
Describes the topography of the area, the geology and mining methods used. A short history of the region is given and the following districts are described: Herberton, Watsonville, Irvinebank, Eureka Creek, Koorboora, Newellton and Coolgarra. The Smith's Creek mine and the lodes on California Creek and Reid's Creek are also described.

896. ———. The Annan River tin field, Cooktown District.

Geol. Surv. Rep. Queensland, Pub., No. 210, 1907, Brisbane, pp. 27, map 1, pls. 14.
Also, Queensland Gov. Mg. Journ., November, 1906, Brisbane.
Abstract: Mg. World, Vol. 26, 1907, Chicago, p. 7.
Tin occurs on Mt. Amos, Mt. Leswell, and at the Lion's Den in granite much altered and tourmalinised along joints. From these the alluvial deposits along the Annan River and its tributaries have been formed. Gives general description of claims.

897. CLELAND, W. LAUDER. Tin dressing at Stannary Hills, North Queensland.

Trans. Austr. Inst. Mg. Eng., Vol. 12, 1907, Melbourne, pp. 154-164, pl. 1, figs. 2.
Description of the mills and some of the principal machinery, also methods employed in dressing of tin ore.

898. CLOTTEN, E. Die Zinn- und Wolfram- Vorkommen von Nord-Queensland.

Min. Mitth., n. f., Vol. 24, 1905, Wien, pp. 137-139.
Digest: Neues Jahrb. Min., 1906, II (Ref.), Stuttgart, pp. 26-27.
Alluvial tin was first discovered in Herberton district, North Queensland, "sometime ago," and afterwards rich deposits were found on Wild River. Older alluvial deposits were later discovered in the Herberton lowland, at Watsonville, Irvinebank, and still later, very rich and extensive tin ore deposits were found in Silver Valley near Herberton. The ores of these deposits contain on an average, 4 per cent of bismuth, 3 to 8 per cent of copper and considerable tungsten. The tin-bearing territory has now been shown to extend over an area of 12,000 square miles.

899. CUSACK, W. G. KELLEY. Ravenswood fields.

Ann. Rep. Under-Secretary for Mines, Queensland, for year 1904 (1905), Brisbane, p. 95.
A short description of the tin camps on Running Creek is given, but nothing is said about the geology.

QUEENSLAND (Continued)

D'ACHIARDI, ANTONIO. *See* No. 1313.

900. DAINTREE, R. Tin in Queensland.

Mg. Journ. Railw. Comm. Gaz., Vol. 42, 1872, London, pp. 680-690.
Also, Quart. Journ. Geol. Soc. London, Vol. 28, 1872, London, pp. 301-302.
At time of writing, discoveries were limited to drainage area of the upper part of the Severn River. These are swampy beds, intersected by numerous broad bars of granite. The alluvial beds vary in thickness from 3 to 20 feet. Outlook very encouraging; the greatest difficulty to overcome will be the swampy character of the ground, especially during the rainy season.

DAVIES, D. C. *See* No. 1317.

901. DOWEL, W. S. The Herberton tin field.

Austr. Mg. Stand., Nov. 17, 1898, Sydney and Melbourne. Serial.
"Information concerning these lode tin deposits in Queensland."
Not available to the authors.

902. DUNSTAN, B. Tin in Queensland.

Ann. Rep. Under-Secretary for Mines, Queensland, for 1904 (1905), Brisbane, p. 149.
The Lancelot Tin Mine at Silver Valley is described, and the general geology of the region is given.

903. ———. Monazite in Queensland.

Geol. Surv. Rep. Queensland, Pub. No. 196, 1905, Brisbane, p. 11.
Brief mention of cassiterite, found in the beach sands at the mouth of the Tweed River, with monazite. A concentrated sample yielded 54 per cent of tin.

904. ———. Stanhills tin fields, Queensland.

Geol. Surv. Rep., Queensland, Pub. No. 211, 1907, Brisbane, pp. 21, maps 2, pls. 3.
Country rock is altered granite, aplite and quartz-felsite. Cassiterite occurs in irregular masses of chlorite and quartz in granite; in quartz veins cutting quartz-felsite; in chlorite veins in quartz-felsite, granite and aplite; chlorite and greisen veins in granite. There are limited tin placers, and the Desert sandstone is tin-bearing, though in what way is not explained. The total yield is small.

905. ———. Stanhills tin fields.

Geol. Surv. Rep., Queensland, Pub. No. 211, 1907, pp. 21.
Queensland Gov. Mg. Journ., Vol. 9, 1908, Brisbane, pp. 285-288, map 1, pls. 3.
Discusses the geology, the mines, the alluvial deposits and prospects of the Stanhills district, Queensland. Cassiterite occurs in altered granite, or in close connection with granite, with much chlorite. Galena, zinc blende, chalcopyrite, and graphite occur with the tin. Alluvial deposits occur in the neighborhood around the head of Ten-mile Creek.

906. EDLINGER, W. Einige Bemerkungen über die Zinnerzlagerstätten des Herberton distrikts in Queensland.

Zeitschr. prakt. Geol., Vol. 16, 1908, Berlin, pp. 275-279 and 340-343.
I. Die primaren Lagerstätten, pp. 275-279.
A description of the lode occurrences.
II. Die Zinnseifen, pp. 340-343.
Description of elluvial, alluvial, and fossil ("deep leads") placers.

FAWNS, SYDNEY. *See* No. 1320.

907. FRYAR, WM. The mineral resources of the colony of Queensland.

Trans. Fed. Inst. Mg. Eng., Vol. 13, 1896-1897, Newcastle-upon-Tyne and London, pp. 358-359.
Enumerates places where tin is found, but gives little more about tin deposits.

QUEENSLAND (Continued)

908. GREGORY, T. F. Tin in Queensland.

Journ. Soc. Arts, Vol. 20, 1872, London, pp. 853-854.

A communication from the Secretary of State for the Colonies to the Council in which he describes the stanniferous country geologically and gives its extent.

909. ———. A report on the tin discoveries in Queensland.

Quart. Journ. Geol. Soc. London, Vol. 29, 1873, London, pp. 1-5.

Abstract: Mg. Journ. Railw. Comm. Gaz., Vol. 42, 1872, London, p. 1105.

Abstract: Geol. Mag., 1872, London, p. 569.

Tin ore discovered in district situated about the head waters of Severn River and its tributaries, comprising area of about 550 square miles. District is described as an elevated granite tableland intersected by ranges of abrupt hills, some 3000 feet above sea. Richest deposits are found in beds of streams and in the alluvial flats along their banks.

910. HALDANE, A. C.

Ann. Rep. Under-Secretary for Mines, Queensland, for 1897 (1898), Brisbane, pp. 102-105.

Progress in mining in the Herberton tin mining district is described.

911. ———. Herberton (Walsh and Tinnaroo) fields.

Ann. Rep. of the Under-Secretary for Mines, Queensland, for 1904 (1905), Brisbane, pp. 68-71.

912. HORSLEY, SYDNEY. Report upon the Kangaroo Hills and Star River mineral fields.

Ann. Rep. Under-Secretary for Mines, Queensland, 1904 (1905), Brisbane, p. 110.

913. HUME, W. C. Report on the Queensland tin fields.

1874, pp. 31.

Not available to the authors.

914. JACK, ROBT. L. Report on the Wild River tin mines.

Geol. Surv. Rep., North Queensland, Pub. No. 9, 1881, Brisbane, pp. 8-10, map 1.

Reconnaissance report upon the tin mines in the vicinity of Wild River.

915. ———. On the Stanthorpe tin mining district.

Geol. Surv. Rep., Queensland, Pub. No. 12, 1882, Brisbane, pp. 1-2.

"As it will be necessary for me to return to the district and make a survey of the field, I confine myself, in the meantime, to putting on record in general terms, the conclusions to which I have been led, and my strong faith in the probability of discovering payable deposits of ore in the rocks from which the vast stream deposits were originally derived."

916. ———. On the tin mines of Herberton, Western and Thompson's Creek districts and the silver mines of the Dry River.

Geol. Surv. Rep., Queensland, Pub. No. 13, 1883, Brisbane, pp. 3-32, with geol. maps 2 and 6 plates of sections.

Abstract: Eng. Mg. Journ. Vol. 37, 1884, New York, p. 353.

The intimate connection of the tin deposits with metamorphosed igneous rocks is shown. The claims in the various districts are treated separately.

917. ———. On the tin mines near Cooktown.

Geol. Surv. Rep., Queensland, Pub. No. 66, 1891, Brisbane, pp. 1-9. Geol. map and 2 sheet plans.

Describes the mines of the region in detail.

QUEENSLAND (Continued)

8. ———. The Kangaroo Hills silver and tin mines.

Geol. Surv. Rep., Queensland, Pub. No. 82, 1892, Brisbane, pp. 1-11, map 1.

Describes the tin mines in the central area of the Kangaroo Hills, the unnamed lodes, the Mount Brown silver and tin mines and a group of mines near Running River crossing.

LOCK, C. G. WARNFORD. *See* No. 1338.

LOUIS, HENRY. *See* No. 1340.

9. MACDONALD, A. R.

Ann. Rep. Under-Secretary for Mines, Queensland, for 1895 (1896), Brisbane, pp. 124-126.

The progress of tin mining in the Herberton District during 1895 is epitomized.

0. ———.

Ann. Rep. Under-Secretary for Mines, Queensland, for 1899 (1900), Brisbane, pp. 13-14.

Reports on Herberton, Kangaroo Hills, Cooktown, Stanthorpe, Ravenswood, Palmer and Port Douglas districts. Herberton yield was largest for year. The reports are devoted to economic progress more than to geology.

1. ———.

Ann. Rep. Under-Secretary for Mines, Queensland, for 1900 (1901), Brisbane, pp. 15-16.

The reports of the wardens of the different mining districts, showing progress in tin mining are summarized.

2. ———.

Ann. Rep. Under-Secretary for Mines, Queensland, for 1904 (1905), Brisbane, pp. 8-10, 16-17.

General review of tin mining throughout the Province during the year with statistics. The volume contains beside, descriptions by their respective commissioners of work done in the various districts.

3. ———. Tin mining in Queensland.

Queensland Gov. Mg. Journ., Apr. 15, 1905, Brisbane.

"Reviewing the condition of tin mining in Queensland."

Not available to the authors.

4. ———. Under Secretary for Mines, The Queensland Mining Industry, Review of the year 1906.

Queensland Gov. Mg. Journ., Vol. 8, 1907, Brisbane, pp. 111-113.

An advance copy of the Annual Report, summarizing economic conditions in the tin mining districts.

5. MACLAREN, J. M. Report on Stannary Hills tin mines, Eureka Creek, Watsonville district (North Queensland).

Geol. Surv. Rep., North Queensland, Pub. No. 146, 1900, Brisbane, pp. 1-2.

Describes the geology, ores and working of the tin mines in the Stannary Hills.

6. MAITLAND, A. GIBB. On the Coolgarra tin mines and surrrounding district.

Geol. Surv. Rep., Queensland, Pub. No. 72, 1891, pp. 1-5. With geol. map and plans.

The geological features and the mines of the district are described.

QUEENSLAND (Continued)

927. MUNDAY, JOHN. Notes on tin mining in and around Herberton, North Queensland.

Austr. Ass. Adv. Sci. Vol. 6, 1895, Sydney, pp. 375-381. Map 1.
Reprint: Mg. Journ. Railw. Comm. Gaz., Vol. 66, 1896, London, pp. 990-991.
Abstract: Eng. Mg. Journ., Vol. 59, 1895, New York, pp. 556-557.

Tin is found both in massive and stratified rocks. Lode mining has been extended from Herberton as a center westward to Watsonville, Irvinebank, Eureka Creek and Koorboora, southwest to Coolgarra, Glenlinedale and California Creek. Alluvial ore occurs from Herberton to the Tate River and Fossilbrook, a distance of 80 miles. In the neighborhood of Herberton, the tin bearing rock is mostly porphyry at the outcrop, but of a granitoid structure in depth; hornblende is in places a constituent. Quotes R. L. Jack in describing tin bearing veins as metamorphosed dikes, probably originally diorite, now mainly of quartzose chlorite and quartzose serpentine. In depth veins develop more quartz. Ore is cassiterite, mostly in lenticular deposits, reaching a length of 40 and 50 feet, and in depth from a few inches to several hundred feet. Yield ranges from 5 to 40 per cent oxide. Wolframite, fluorspar, galena and molybdenite occasionally accompany the tin. Alluvial tin is derived from open gullies and gravels now covered by lava. Ilmenite and gem stones sometimes accompany ore.

928. NEWLAND, D. H. Tin in Queensland.

Min. Ind. for 1902, Vol. 11, 1903, New York and London, p. 593.
Brief summary of tin mining conditions in Queensland.

929. NEWMAN, G. H. Kangaroo Hills mineral field.

Ann. Rep. Under-Secretary for Mines, Queensland, for 1904 (1905), Brisbane, pp. 82-84.
The progress of tin mining in the Kangaroo Hills district during 1904 is summarized.

929a. NICHOLAS, C. E. Stannary Hills mines, N. Q.

Queensland Gov. Mg. Journ., Vol. 10, 1909, Brisbane, pp. 552-554. Illus.
Reports for six months, April, 1909, to September, 1909.

PHILLIPS, J. A., and LOUIS, H. *See* No. 1350.

REYER, EDUARD. *See* No. 1354.

ROLKER, CHAS. M. *See* No. 1357.

930. RUSSELL, MURRAY. Report on the Walsh and Tinaroo mineral field and Hodgkinson gold field.

Ann. Rep. Under-Secretary for Mines, Queensland, for 1904 (1905), Brisbane, pp. 111-115.

931. SELLHEIM, P. F. Report of mining industry of Queensland for year 1895.

1896, Brisbane, pp. 32-34.
Treats briefly the tin of Herberton and surrounding districts.

932. ———.

Ann. Rep. Under-Secretary for Mines, Queensland, for 1896 (1897), Brisbane, pp. 102-104.
Reviews tin mining during 1896 and shows that there was some reduction in the output.

933. SHORT, C. H. Stanthorpe and Pikedale fields.

Ann. Rep. Under-Secretary for Mines, Queensland, for 1904 (1905), Brisbane, pp. 100-101.
Notes on the mining progress of the Stanthorpe and Pikedale tin mining fields during 1904.

QUEENSLAND (Continued)

4. SKERTCHLY, SYDNEY B. J. Report on the deep (tin) lead at Herberton.

Geol. Surv. Rep., Queensland, Pub. No. 115, 1896, Brisbane, pp. 1-15, pls. 1-5. (Map, 1 inch=40 chains.)

Discussion of geological conditions, history, and description of tin workings.

5. ———. Tin mines of Watsonville, and various tin, silver, copper and gold mines at Herberton, Montalbion, Irvinebank, Muldiva, Calcifer, Chillagoe, California Creek, Tate River, etc.; also geological notes on Myola, on the recovery of the lost lodes and on the copper plant.

Geol. Surv. Rep., Queensland, Pub. No. 119, 1897, Brisbane, pp. 64, pls. 18, figs. 37.

Describes various mines of the Watsonville district, with geology of the surrounding country. Gives statistics of the region. Notes tin ore that is phosphorescent when heated. Considers the tin mines of the region unsurpassed.

6. ———. On the geology of the country round Stanthorpe and Warwick, South Queensland, with special reference to the tin and gold fields, and the silver deposits.

Geol. Surv. Rep., Queensland, Pub. No. 120, 1898, Brisbane, pp. 98, pls. 3, maps 2 and text figs.

Gives a general article on tin showing distribution; output; percentage in ores of famous mines; table giving associated rocks, mineral, etc.; output; origin; minerals containing traces of tin. Thinks tin was deposited from solution. Detailed description of mines.

7. STAINES, ARTHUR. Port Douglas district.

Ann. Rep. Under-Secretary for Mines, Queensland, for 1904 (1905), Brisbane, p. 87.

Report of mining progress in the Port Douglas tin mining fields during 1904.

8. STERLING, JAMES. Monograph on the geology and mining features of Silver Valley, Herberton, North Queensland, Australia.

Two parts, 1905, Hamburg.

Part I, pp. 41, 5 pp. geologic maps and sections, text figs.

Part II, pp. 16, 1 p. of 35 figs.

Part I deals with the geology and veins of a portion of the country adjacent to Dry River. Describes veins carrying silver, lead, tungsten, copper, bismuth and tin. Considers the mineral deposits of deep-seated origin.

Part II deals with the microscopic characters of the rocks.

9. WEEDON, THORNHILL. Queensland, past and present. An epitome of its resources and development.

1898, Brisbane, pp. 252-253.

Tin is found on the Pascoe River, at Bloomfield, on Palmer River, the Barron Waters, at Herberton including Irvinebank, on the Star River and at Stanthorpe. Mineral first discovered at Stanthorpe in 1872. Production and export value for each year from 1872 to 1896 given. Queensland is third amongst the seven colonies as a tin-producing district coming after New South Wales and Tasmania.

10. WILLIAM, J. VIVIAN. Tin production in Queensland.

Mg. Journ. Railw. Comm. Gaz., Vol. 47, 1877, London, p. 601.

Describes the mineral resources along Hopkinson and Palmer rivers, Queensland, and possible effect the tin deposits might have on the Cornwall tin trade.

10a. WILLIAMS, G. W. Tin mining and milling in North Queensland.

Eng. Mg. Journ., Vol. 87, 1909, New York, pp. 1092-1094.

Treats of mining conditions, describing operations of various companies of North Queensland.

RUSSIA

941. ANONYMOUS. Russische Bergwerksverhältnisse.
Berg. Hütt. Zeit., Vol. 52, 1893, Leipzig, p. 328.
Gives the tin production of Russia, also the amount imported for years 1888, 1889, 1890.

942. ———. Tin in Russia.
Mg. Journ. Railw. Comm. Gaz., Vol. 81, 1907, London, p. 219.
Translation from "Viestnik Frnansoff." The tin situation in Russia is serious, since the closing of the Pitkäranta tin smelter. Russia imported in 1904, 301,000 poods. Pitkäranta deposits are of little value. Recommends attention to deposits on Onon River, Transbaikal region, where the tin outlook is encouraging.

BORGSTRÖM, L. H. *See* No. 1594.

COTTA, BERNARD VON. *See* No. 1312.

943. FIEDLER, K. G. Ueber die alten Zinnstein-Gruben am Onon in Dauurien (Ononsky Priski Olowennoi Sawod).
Arch. Miner. Geogn. Bergb. Hütt., Vol. 12, 1839, Berlin, pp. 178-188.
Digest: Neues Jahrb. Min., 1841, Stuttgart, p. 714.
Tin deposits are located 87 "werst" from the junction of Onon and Ingoda rivers. Tin occurs in segregations in granite dikes cutting hornblende schists. Wolframite occurs with ore in some places.

GADOLIN, S. A. *See* No. 1612.

944. GURNEY, H. P. Notes on the geology of Finland.
Trans. Fed. Inst. Mg. Eng., Vol. 15, 1898, Newcastle-upon-Tyne and London, pp. 147, 152.
Mentions the deposits of tin at Pitkäranta, on the northeastern shore of Lake Ladoga. Production is small.

945. HERMANN, R. Untersuchungen russischer Mineralien. Ueber das Vorkommen von gediegenem Zinn in den Ural'schen Goldseifen.
Journ. prakt. Chem., B. 33, 1844, Leipzig, p. 300.

946. KEPPEN, A. DE. Aperçu général sur l'industrie minérale de la Russie.
Ann. Mines, ser. 9, Vol. 5, 1894, Paris, pp. 233-234.
Treats very briefly of tin in Finland.

KOULIBINE, S. *See* Nos. 1690, 1691 and 1692.

947. KRUSCH, P. Ueber sicht über die nutzbaren Lagerstätten Russlands.
Zeitschr. prakt. Geol., 1897, Berlin, p. 277.
States that lode tin is found at Pitkäranta, Finland, and that stream tin is found along the Onon River, Siberia.

LOUIS, HENRY. *See* No. 1340.

948. NORDENSKIÖLD, A. E. Beitrag zu Finnlands mineralogie.
[Trans.] Ann. Physik. Chem., Vol. 101, 1857, Leipzig, pp. 625-642.
Brief digest, Neues Jahrb. Min. 1858, Stuttgart, p. 467.
Tin of Pitkäranta treated.

———. *See* No. 1628a.

PHILLIPS, J. A., and LOUIS, H. *See* No. 1350.

RUSSIA (Continued)

949. PUSCH, GEO. G. Kupfer- und Zinnerz-Bau am Ladoga-See; Geognosie Finnlands und von Petersburg.

Neues Jahrb. Min., 1836, Stuttgart, pp. 197-199.

A communication written Dec. 1835, giving an account of the tin occurrences in Finland.

950. SCHOULTZ-ASCHERADEN, G. VON. Die Kupfer- und Zinnerz-Lagerstätte zu Pitkäranta in Finnland.

Berg. Hütt. Zeit., Vol. 35, 1876, Leipzig, pp. 280-281. Mit. fig. 8 u. 9 auf Taf. 13.

951. STRUVE, H. VON. Tin in Russia.

Neues Jahrb. Min., 1834, Stuttgart, p. 398.

The announcement of a discovery of tin ore at Pitkäranta, communicated in a letter by H. von Struve.

952. TÖRNEBOHM, A. E. Om Pitkäranta malmfält och dess omgifningar.

Geol. För. Stockholm Förh., Vol. 13, 1891, Stockholm, pp. 324-325, map 1.

Description of the tin of Pitkäranta, Finland.

953. TRÜSTEDT, OTTO. Die Erzlagerstätten von Pitkäranta am Ladoga-See.

Bull. Com. Géol. de Finland, No. 19, 1907, Helsingfors, pp. 333, with geol. map 1, pls. 19 and text figures 80. Pp. 140-151, and others.

Reviewed by Knopf, Adolph, Econ. Geol., Vol. 3, 1908, Lancaster, pp. 540-542.

"This monographic report of ore deposits of Pitkäranta, is interesting from three standpoints: As a study of contact, metamorphism; as an investigation of pre-Cambrian ore-deposits in highly metamorphic rocks, and as an application of magnetometry to the location and computation of iron-ore reserves.

"Briefly, Pitkäranta is characterized as an iron-ore district locally rich in copper and tin ores. The latter deposits are quite fully treated."

SANTO DOMINGO

954. GARSTON, E. M. DE. Mineral Resources of the Dominican Republic.

Mg. Journ. Railw. Comm. Gaz., Vol. 83, 1908, London, p. 682.

States that "Tin deposits are said to exist in Seybo and in the Higuel, Province of Seybo." Quoted from a British Consular Report.

SCOTLAND

FAWNS, SYDNEY. *See* No. 1320.

955. FLETT, J. S., and CLOUGH, C. T. Tinstone in Scotland.

Mem. Geol. Surv., Summ. Progr. Geol. Surv. United Kingdom and Mus. Pract. Geol. for 1903 (1904), London, pp. 2, 59-60.

First recorded occurrence of tinstone in Scotland. Occurs with magnetite. No indication that it occurs in any quantity.

SIAM

956. ANONYMOUS. A note on mining in Siam. A reprint from the copyright publications of the Royal Commission for the Louisiana Purchase Exposition.

Published by Mining Department of Siam, 1904, pp. 3-4.

Gives a list of the districts in which alluvial tin is mined, and states that the possibilities of tin mining in Siam are large.

SIAM (Continued)

957. ———. Mining in Siam.

Eng. Mg. Journ., Vol. 79, 1905, New York, p. 190. Probably taken from the Siamese Louisiana Purchase Exposition Publication. See No. 960.

Tin is the only metal, the working of which is of any importance in Siam. Deposits of importance are derived from, and lie adjacent to, the great granitic range which forms the boundary between central Siam and Tenasserim, and the backbone of the Malay Peninsula.

958. ———. Tin mining in Siam.

Écho des Mines, April 29, 1907.

Quoted in Mg. Journ Railw. Comm. Gaz., Vol. 81, 1907, London, p. 593.

Tin mined principally in the provinces of Puket and Kedah. Annual production about 5000 tons. Vast district yet unexplored, which probably contains considerable mineral wealth.

959. BLEWETT, JASPER. Tin mining in the Straits Settlement.

Eng. Mg. Journ., Vol. 22, 1876, New York, p. 156.

An account of the tin mining on Junk-Seylon or Salanga, an island on the coast of Lower Siam.

960. CARTER, A. CECIL. Editor. The kingdom of Siam.

Published by the Ministry of Agriculture for Louisiana Purchase Exposition, 1904. New York, pp. 241-243, 500 words.

Small amounts of tin are found in the valley of the Nam Sak River. Tin placers are worked in the following provinces: East Coast—Ratburi, Bangtaphan Langsuan, Chaija, Bandon, Lakon, Jalar, Rangeh, Rahman, Kelantan, Tringanu. West Coast—Kra, Renong, Takupar, Panga, Takuatung, Puket, Trang, Stul, Perlis, Kedah. Annual production about 5000 long tons, valued at $3,000,000. Puket Island on the West Coast is the most important field. Most promising for future developments are Kedah Rahman, Jalar, Takuatung and Renong. Work mostly in hands of Chinese. One American, one English, and one Dutch firm at work. There is an enormous field for the expansion of the tin-mining industry in the Siamese possessions in the Malay Peninsula.

D'ACHIARDI, ANTONIO. *See* No. 1313.

FAWNS, SYDNEY. *See* No. 1320.

961. FISCHER, H. Ueber siamesische Mineralien.

Neues Jahrb. Min., 1882, II, Stuttgart, p. 196.

Tin is the most important mineral of Siam. Alluvial tin is found in provinces of Xaláng, Xaija, Xumphon, Rapri and Pak-Phrëk.

REYER, EDUARD. *See* No. 1354.

962. SCOTT, H. G. A note on mining in Siam.

Mg. Journ. Railw. Comm. Gaz., Vol. 76, 1904, London, p. 185.

Practically the same as No. 960 from which it seems to be largely taken.

See also Laos.

SIBERIA

963. ANONYMOUS. Tin in Siberia.

Min. Ind. for 1900, Vol. 9, 1901, New York and London, p. 640.

Notes recent discoveries of tin on the Onon River.

SIBERIA (Continued)

964. ———. Zinnerzlager in Ost-Sibirien.

Zeitschr. prakt. Geol., 1901, Berlin, p. 245.

Brief digest: Eng. Mg. Journ., Vol. 71, 1901, New York, p. 240, taken from "Engineering," London.

Notice of the deposits of tin in Province Transbaikalien, near Onon River and tributaries. Its situation is fortunate, being easy of transportation, and nearness to the forest facilitates working.

D'ACHIARDI, ANTONIO. *See* No. 1313.

FAWNS, SYDNEY. *See* No. 1320.

965. FONIAKOFF, ANTONIN. The gold deposits of Siberia.

Trans. Fed. Inst. Mg. Eng., Vol. 7, 1894, Newcastle-upon-Tyne and London, pp. 447, 466, 479.

For more than a century and a half in the Transbaikal, silver, gold, lead, iron, copper, mercury and tin have been worked.

966. ———. Les richesses miniéres de la Sibèrie.

Rev. Univ. Mines Mét. Trav. Publ. Sci. Arts Appl. Indust., ser. 3, Vol. 29, 1895, Liége and Paris, p. 129.

967. GLASSER, E. Note sur les richesses minérales de la Sibèrie et sur l'etat actuel de leur exploitation.

Ann. Mines, ser. 9, Vol. 18, 1900, Paris, p. 53, maps.

Mentions that tin is found in the valley of the Onon.

968. HERMANN, R. Sur l'étain natif.

Extrait: Journ. prakt. Chem., Vol. 33, 1844, Leipzig, p. 300.

Ann. Mines, ser. 4, Vol. 8, 1845, Paris, p. 660.

M. Hermann indique la présence de l'étain natif avec l'or, dans les lavages d'or de la Sibérie. Il s'y trouve sous la forme de petits grains métalliques gris qui sont de l'étain allié d'un peu de plomb. Ces grains sont du reste peu abondants. [Whole extract.]

JEREMEJEV, P. *See* No. 1622.

969. KEPPEN, A. Mineral wealth of Siberia.

Industries of Russia, Vol. 4, 1893, St. Petersburg, pp. 30-31.

(For the World's Columbian Exposition at Chicago. Trans. by J. M. Crawford.)

Reprint: Mg. Journ. Railw. Comm. Gaz., Vol. 65, 1895, London, p. 243.

Deposits of tin are known only in Finland and Baikal province of Siberia. Production under 20 tons. Since yearly demand of Russia is over 100,000 poods, internal production is utterly insufficient for home consumption.

970. KORZOUKHINE, J. A. Gisements de minerais d'étain sur la Rivière Onon.

Bull. No. 4, Soc. Ing. Mines, 1899, St. Petersburg, pp. 22-35.

Digest: Trans. Inst. Mg. Eng., Vol. 17, 1900, London and Newcastle-upon-Tyne, pp. 642-646.

"With the exception of Pitkäranta, where the production of tin is insignificant, the only Russian deposits of cassiterite are in the territory of the Transbaikal, on the River Onon and its affluents."

971. RÉONTOVSKI, —. Les gisements miniers dè la Sibérie.

(Bulletin) Rev. Univ. Min. Mét. Trav. Publ. Sci. Arts Appl. Indust., ser. 4, Vol. 12, 1905, Paris and Liége, p. 204.

Les gisements de cassitérite sont connus dans la vallée de la Rivière Onon, en Transbaïcalie. Leur exploitation exige une preparation mecanique importante.

SOUTH AMERICA

See under Argentine Republic, Bolivia, Chili, French Guiana, Peru.

SOUTH AUSTRALIA

972. ANONYMOUS. Tin in South Australia.

Min. Ind. for 1900, Vol. 9, 1901, New York and London, pp. 637-638.

Discovery of tin ore near Erea Dam, in quartz vein, reported. Prospects seem encouraging.

973. BROWN, H. Y. L. Report on the Koetong tin field, Wodonga district.

Reports of the Mining Surveyors and Registrars, 1873, (App. A.), Melbourne, p. 42. Quoted in Mg. Journ. Railw. Comm. Gaz., Vol. 43, 1873, London, p. 1220.

Tin-field comprises large area between Murray and Mitta-mitta rivers. Bed rock is granite of various kinds, mostly coarse with black and white mica in large plates. Deposit varies from few inches to 2 or 3 feet thick. Wash dirt made up of boulders and angular fragments of granite and quartz. Ore is disseminated all through wash, and also in layers, but more plentiful on or near bed rock. No lodes of workable size found. Lists of principal claims given.

974. ———. Report on the gold discovery at Tarcoola, the Enterprise Mine, the Earea Dam tin find and the Mount Gunson copper mine.

Rec. Mines, South Australia, 1900, Adelaide, p. 6.

The tin discovery is situated 1½ miles south of Earea Dam, on a mud lake where the surface sand and loam have been eroded, and expose granite, diorite and other hornblendic rocks containing quartz. A dishful of the alluvial soil over the tin vein outcrop yielded 1 pound, 10 ounces of tin; on being smelted, it gave 1 pound tin or 90 per cent. Prospectors have sunk in the quartz veins, but would probably meet with more success in prospecting for alluvial tin.

FAWNS, SYDNEY. *See* No. 1320.

SOUTH DAKOTA

975. ANONYMOUS. The Black Hills of Dakota. [Tin ore.]

Eng. Mg. Journ., Vol. 36, 1883, New York, p. 111.

A communication from one who had visited the mines.

976. ———. Tin in the Black Hills.

Eng. Mg. Journ., Vol. 38, 1884, New York, p. 358.

Editorial: Brief review of the effect of Prof. Chas. A. Schaeffer's paper, "Note on tantalite and other minerals accompanying the tin ore in the Black Hills." Trans. Amer. Inst. Mg. Eng., Vol. 13, 1884-1885, New York, pp. 231-233.

977. ———. An immense tin deposit.

Mg. Sci. Press, Vol. 48, 1884, San Francisco, p. 34.

A very enthusiastic and exaggerated account of a recent tin discovery in the Black Hills. Statements are made that discovery will "revolutionize the trade." "Deposits are so vast as to be able to supply the whole world for centuries."

978. ———. The tin mines of Dakota.

Eng. Mg. Journ. Vol. 42, 1886, New York, pp. 325-326.

Editorial on the outlook of the Dakota tin mines.

SOUTH DAKOTA (Continued)

———. The waning probabilities of finding paying mines in Dakota.
Eng. Mg Journ., Vol. 48, 1889, New York, p. 312. About 500 words.
Editorial on the effort of Harney Peak Tin-mining Co., to boom their mines. The company has induced many English, and are now endeavoring to induce the French to invest in stock.

———. Nigger Hill tin district (South Dakota).
Eng. Mg. Journ., Vol. 50, 1890, New York, p. 555.
Short account of the finding of stream tin in the placer gold; excitement aroused; forming of companies; working of deposits.

———. The Harney Peak tin deposits.
Mg. Journ. Railw. Comm. Gaz., Vol. 62, 1892, London, pp. 1210-1215. Illus.
General description of the property, when and how tin was discovered in the Black Hills, the opinions of experts, present position of the properties and their possible future.

———. The Harney Peak tin mines.
Mg. Journ. Railw. Comm. Gaz., Vol. 62, 1892, London, p. 1357.
Extract from "Hill City Tin Miner," of Nov. 18, 1892, detailing the working of the new mill.

———. The tin ore concentrating plant at Harney Peak, South Dakota.
Eng. Mg. Journ., Vol. 54, 1892, New York, pp. 102-104.
Reprint: Ann. Rep. Secr. Min. Wat. Supp. of Victoria for 1892 (1893), Melbourne, p. 52.
Two pages devoted to plans of Harney Peak tin ore concentrating mill. Article describes methods used and results obtained.

———. Tin at Nigger Hill, South Dakota.
Mg. Sci. Press, Vol. 89, 1904, San Francisco, p. 19.
The Tinton Co., on Nigger Hill, Lawrence Co., South Dakota, has the distinction of being the only concern in America at present, crushing and concentrating tin ore. Ore occurs in large dikes of coarse granite, similar to that in Harney Peak region.

———. Tin in United States.
Mg. Sci. Press, Vol. 89, 1904, San Francisco, p. 385. Illus.
The Nigger Hill-Bear Gulch region on the South Dakota-Wyoming line has received much encouragement in the development of the industry. The Tinton Tin Co., has been operating a small concentrating plant. Cassiterite occurs in dikes of granite of very coarse crystallization.

———. South Dakota.
Mg. World, Vol. 22, 1905, Chicago, pp. 412-413.
A stamp mill and tin concentrating plant which have been erected will treat tin and gold ore taken from a shaft 500 feet deep which has been sunk on the old Gertie property.

———. Tin in Dakota.
Eng. Mg. Journ., Vol. 79, 1905, New York, p. 469.
Brief account of recent discovery of tin ore at Tinton, Lawrence Co., S. D.

———. Tin mining in South Dakota.
Eng. Mg. Journ., Vol. 88, 1909, New York, p. 828.
Short description of tin mill of Tinton Milling Co., Tinton, S. D.

BAILEY, GILBERT E., and RIOTTE, E. N. Harney Peak Tin Mining, Milling and Manufacturing Company.
1886, New York, pp. 77.
Reports on the property of the company.

SOUTH DAKOTA (Continued)

BECK, RICHARD. *See* No. 1299.

989. BENEDICT, WM. DE L. Prof. Vincent's estimates of possible profits of the Harney Peak tin mines (Dakota).

Eng. Mg. Journ., Vol. 48, 1889, New York, pp. 358-359.
A brief review and criticism of Prof. Vincent's report on the mine.

990. ———. Tin in South Dakota.

Min. Ind. for 1892, Vol. 1, 1893, New York and London, pp. 453-455.
Short account of the discovery of tin and the early history of development.

991. BLAKE, W(ILLIAM) P. The discovery of tinstone in the Black Hills of Dakota.

Eng. Mg. Journ., Vol. 36, 1883, New York, pp. 145, 163-164, 344; Vol. 38, August 2, 1884, p. 69.
Summary: Amer. Journ. Sci., ser. 3, Vol. 26, 1883, New Haven, p. 235. Same material in Min. Res. U. S. for 1883-1884, U. S. Geol. Surv., Washington, D. C., pp. 592-640.
Reviews occurrence of tin in U. S. Special description of Black Hills occurrence. Notes on foreign occurrences. A good paper.

992. ———. Tin ore of the Etta mine, Dakota.

Eng. Mg. Journ., Vol. 38, 1884, New York, p. 69.
An addition to author's article of September of year before. The accompanying minerals are named and briefly described.

993. ———. Columbite and tantalite with the tin ore of the Black Hills.

Eng. Mg. Journ., Vol. 38, 1884, New York, p. 376.
Interesting communication explaining the difficulty occasioned by Prof. Schaeffer's analysis of a sample sent to him for examination. It was not sent as tin ore, but as a specimen to be analyzed, the nature of which the superintendent wished to know. It was analyzed as tantalite and from this went abroad the report that there was no tin ore, but tantalite, in the Black Hills.

994. ———. Tin ore in the Black Hills, Dakota.

Min. Res. of U. S. 1883-1884, U. S. Geol. Surv., 1885, Washington, D. C., pp. 602-[illegible].
Treated under following subjects:
The discovery of tin at the Etta mine; geological horizon; development work at the Etta mine; concentric structure of the Etta vein; varieties of ore at the Etta claim; greisen rock carrying tinstone; percentage of tin in the greisen; Bob Ingersoll claim; western slope of Harney range; tin discovered at Dogtown; area of the tin region; stream tin in Dakota. An excellent account of the geology and development of the Black Hills tin district.

995. ———. Tin ore veins in the Black Hills of Dakota.

Trans. Amer. Inst. Mg. Eng., Vol. 13, 1885, New York, pp. 691-696.
Digest: Oest. Zeitschr. Berg. Hütt., Vol. 33, 1885, Wien, p. 302.
Treated under: Structure of the Etta vein; percentage of black tin in the ore; minerals associated with the tin ore; extent of the tin region; contemporaneous origin of the ore and rock.

996. ———. Tantalite and columbite in the Black Hills of Dakota.

Trans. Amer. Inst. Mg. Eng., Vol. 13, 1885, New York, pp. 696-697.
"There are two localities where the mineral (tantalite or columbite) is found in the same dike or vein as the cassiterite: (1) at the Etta mine; (2) at the Bob Ingersoll claim."
Gives observations upon the occurrence of the minerals with the tin ore. States that one mass of columbite or tantalite from the Ingersoll claim weighed approximately, 2000 pounds. (Digest by Cleophas C. O'Harra.)

SOUTH DAKOTA (Continued)

———. Cassiterite, spodumene and beryl in the Black Hills, Dakota.

Amer. Journ. Sci., Vol. 26, 1883, New Haven, p. 235.

Brief review: Neues Jahrb. Min., 1885, II (Ref.), Stuttgart, p. 4.

A short description of the manner in which tin ore occurs in the Black Hills.

CARPENTER, FRANKLIN R. Tin in the Black Hills.

Preliminary Report Dakota School of Mines, upon the Geology, Mineral Resources and Mills of the Black Hills of Dakota, 1888, Rapid City, pp. 133-166, figs. 2.

The paper is divided into two parts:

1. Relating to the Black Hills tin.
2. Relating to the subject of tin generally.

The occurrence of tin in the Black Hills, including its geology, extent and mode of treatment, also information compiled from the works of others that may be of benefit to the mining prospector and mining companies preparing to work deposits. A number of assays are given.

———. Ore deposits of the Black Hills of Dakota.

Trans. Amer. Inst. Mg. Eng., Vol. 17, 1889, New York, pp. 570-598, colored map, fig. 1.

Practically same thing in Min. Res. U. S. for 1888, U. S. Geol. Surv. 1890, Washington, D. C., pp. 149-156.

General statement of occurrence of tin ore. Mentions presence of mineral autunite. Says that when all three constituents of granite are present no tin is found. Any two get tin. Mentions galena, graphite, barite, ilmenite as accompanying minerals. Thinks both granite and tin are deposited by solutions. Says tin has been found near veins in the country rock. Not very reliable paper.—L. C. Graton.

———. Tin in the Black Hills.

In Pa-Ha-Sa-Poh, or the Black Hills of South Dakota, by Rosen, Peter, 1895, St. Louis, pp. 636-645.

Gives an account of the discovery, the occurrence and character of the veins and the accompanying minerals, and likens the veins to those of Zinnwald.

———. Tin in the Black Hills, South Dakota.

Mg. World, Vol. 25, 1906, Chicago, pp. 600-601. Sketch showing formation of the Black Hills' tin deposits.

The writer believes with increased price of tin and improvements in mining machinery, that tin mining in Black Hills will yet be an industry that will rank second to gold mining of that section.

CARPENTER, F. R., and HEADDEN, W. P. *See* No. 1466.

CHANCE, H. M. Resources of the Black Hills and Big Horn Country, Wyoming.

Trans. Amer. Inst. Mg. Eng., Vol. 19, 1891, New York, pp. 49-58. Read New York meeting September, 1890.

Gives result of an examination made in 1887-1888 of the country lying between the Black Hills and Big Horn Mountains. Refers briefly to the structure, resources and scenery of the Hills. Thinks there will be a considerable output of tin from the southern hills, especially from about Custer City.

CLAYPOLE, E. W. Tin islands of the northwest.

Amer. Geol., Vol. 9, 1892, Minneapolis, pp. 228-236.

Detailed account of geologic history of Black Hills with only short space devoted to tin. Thinks granite masses are segregated veins, since they conform with the schists.

DAY, DAVID T. Tin.

Min. Res. U. S. for 1887, U. S. Geol. Surv., 1888, Washington, D. C., pp. 134-137.

SOUTH DAKOTA (Continued)

A review of work done and tin mines opened in the Black Hills, Dakota. "Cleveland" mine was selected for heaviest operations. Hoisting plant and suitable buildings have been erected. Three tons of stream tin and 250 pounds of metallic tin have been shipped.

1005. ———. Dakota tin mines.

Min. Res. U. S. for 1888, U. S. Geol. Surv., 1890, Washington, D. C., pp. 144-150.
Review: Neues Jahrb. Min., 1891, II (Ref.), Stuttgart, 237-238.
Present outlook reported as very encouraging. Character of veins; analyses of cassiterite from veins; percentage of black tin in the rock; treatment of the ore; yield of metallic tin.

1006. EMMENS, STEPHEN H. Tin in South Dakota.

Eng. News Amer. Railw. Journ., Vol. 28, 1892, New York, pp. 208-209.
Author gives what seems to be a careful and apparently unprejudiced statement concerning the South Dakota tin.

1007. GARRISON, F. LYNWOOD. Tin in the Black Hills.

Eng. Mg. Journ., Vol. 78, 1904, New York, p. 830.
Review of work done.
Geology of the district.

1008. HEADDEN, WM. P. Notes upon the history of the discovery and occurrence of tin ores in the Black Hills of South Dakota.

Proc. Colorado Sci. Soc., Vol. 3, 1890, Denver, pp. 347-350.
A good article upon the general geology of the deposits. Thinks there are two kinds of deposits: (1) original in the granites; (2) secondary in quartz veins. Says the granite (i. e. pegmatite) is pre-Cambrian.
"States that the earliest identification of tin from the Black Hills was in 1876 by Mr. Richard Pearce of Denver, Colo., who detected cassiterite as stream tin in gold dust from the Northern Hills. The second discovery was made on Elk Gulch, southern section, in April, 1877. The material from the latter place was assayed by Theo. Vosburg, but the true nature of the bullion was first recognized by Mr. Fred J. Cross. Dates of various other discoveries and remarks on the general geology of the region are also given." (Digest by Cleophas C. O'Harra.)

———. *See* No. 1616.

1009. HESS, FRANK L. Tin, tungsten and tantalum deposits of South Dakota.

U. S. Geol. Surv. Bull., 380, 1909, Washington, D. C., pp. 131-163, text fig. 1.
Abstract: Mg. World, Vol. 31, 1909, Chicago, pp. 457-460.
Cassiterite occurs in the southern Black Hills in pegmatite dikes and in quartz veins. The quartz veins also carry important amounts of wolframite which sometimes forms beautiful intergrowths with light colored cassiterite. Many other minerals occur in the pegmatites with the cassiterite, including spodumene, amblygonite, lepidolite, apatite, tantalite, columbite, pyrite, arsenopyrite, chalcopyrite, tourmaline, etc., but there is little or no fluorite, topaz, or axinite. The dikes which carry most tin are the finer-grained and carry the least number of accessory minerals. The quartz veins are probably a later phase of the same intrusions which formed the pegmatites, and the two grade into each other.
In the northern Black Hills, at Tinton, tin occurs in pegmatites, similar to those in the southern Hills, but with fewer accessory minerals.

HOFMAN, HEINRICH O. *See* No. 1506.

1010. IRVING, JOHN DUER. Economic resources of the Northern Black Hills.

U. S. Geol. Surv., Prof. Paper No. 26, 1904, Washington, D. C., pp. 95-97.

SOUTH DAKOTA (Continued)

Gives a short history of the discovery of tin in the Black Hills and the efforts to mine it. States that cassiterite occurs at Nigger Hill in Cambrian pegmatitic granite which is an inclusion in Tertiary acid porphyry. Columbite, tantalite, tourmaline, and wolframite accompany the cassiterite. The cassiterite is irregularly distributed through the granite, and may possibly be mined on a small scale at a profit.

Says topaz accompanies stream tin in the creeks of the area.

———. The ore deposits of the Northern Black Hills.

Mg. Rep. Vol. 50, 1904, Denver, pp. 430-431.

Some tin occurs in the Algonkian schists. "The tin ore also occurs in placers as stream gravels, derived from distintegration of the country rock containing tin. The cassiterite in these gravels is but little rounded and differs in its black color from the reddish brown type of stream tin." See No. 1010.

[illegible]——, H. Tin mines in the Black Hills of Dakota.

Mg. Journ. Railw. Comm. Gaz., Vol. 61, 1891, London, p. 694.

Extracts from report of English Consul at Chicago. Speaks of tin outlook as very encouraging from various reports of experts. Describes deposits chief of which are found in Custer and Pennington counties, as veins, varying from a foot to more than 300 feet in width, and in length from a few yards to 5 miles. Outcrops are from a few feet to 150 feet above surface. Abundant fuel at hand.

HORSE, ARTHUR J. The Harney Peak tin mines.

Eng. Mg. Journ. Vol. 58, 1894, New York, p. 463.

Summary of surface developments. Says surface indications are not borne out in depth. Describes and gives illustration of pinching out of "greisen" band, and says quartz veins do the same.

O'HARRA, CLEOPHAS C. The mineral wealth of the Black Hills (South Dakota). Tin.

South Dakota, Geol. Surv. Bull. No. 3, Mineral Resources of South Dakota, 1902, Vermillion, pp. 62-67.

Gives a general sketch of the geology of the Black Hills and describes the occurrence of the minerals.

ROSEN, PETER. *See* No. 1000.

S(TORMS?), W. H. Bear Gulch tin district, South Dakota.

Mg. Sci. Press, Vol. 86, 1903, San Francisco, pp. 198-199.

This district is of unusual interest, as in it occur both mines of gold and tin. The gold miners were greatly hampered in their sluicing, by the abundant occurrence of black sand and small pebbles of high specific gravity which filled riffles and caused loss of gold. About 1880 it was discovered that this sand—at least part of it, was cassiterite. Other minerals of economic importance in this district are, wolframite and columbite-tantalite.

SADTLER, B. Gold and tin in Northwestern Black Hills.

Mg. World, Vol. 25, 1906, Chicago, pp. 520-522, sections 5.

Editorial on same: Ibid., p. 517.

Treats of gold and tin bearing districts in Crook Co., Wyoming, and Lawrence Co., South Dakota. "The district shows proper geologic conditions being identical with the historic Deadwood district, with addition of a large belt of tin veins. It is admirably located as regards wood, water and all necessary supplies, as well as being within the reach of railroads. It has exposed and partly developed large bodies of gold and tin ore in vein, and large and quickly available amounts of the same metals in placers, all of pay grade. Incidental to the extraction of the above metals, mica and tungsten form a probable source of income."

SOUTH DAKOTA (Continued)

1017. SCHAEFFER, CHAS. A. Note on tantalite and other minerals, accompanying the tin ore in the Black Hills.

Trans. Amer. Inst. Mg. Eng., Vol. 13, 1884-1885, New York, pp. 231-233.

The analysis of some ore from Etta mine which at first seemed like tin ore, but proved to be tantalite. This report caused a great stir among mining men, thinking Prof. Schaeffer intended to show that the supposed tin ore was tantalite. Such was not the case. The specimen sent for examination was not sent as tin ore, but as an unknown ore which proved to be the above-named mineral.

1018. SIMMONS, JESSE. Review of South Dakota mining conditions.

Mg. Rep., Vol. 50, 1904, Denver, p. 63, photos 3, 2700 words.

"Illustrated description of the Black Hills gold and tin mines. Gives monthly tonnage, treatment and value of the different ores."

1019. ———. Tin mining, metallurgy and geology, Black Hills.

Mg. Rev., May 25, 1906, Los Angeles.

Not available to the authors.

1019a. ———. Tin in the Black Hills of South Dakota.

Mg. World, Vol. 30, 1909, Chicago, pp. 925-926, sketch 1.

Extract: Mg. Journ. Railw. Comm. Gaz., Vol. 85, 1909, London, p. 703.

"A short historical review of tin mining in the Black Hills, with notes on the geology of the district and the operations of the Harney Peak Company."

1020. STRUTHERS, JOSEPH, and PRATT, JOSEPH HYDE. Tin in South Dakota and Wyoming.

Min. Res. for 1903, U. S. Geol. Surv., 1904, Washington, D. C., pp. 335-336.

A new district has been worked for past two years, located partly in Lawrence Co., South Dakota, and partly in Crook Co., Wyoming. Cassiterite occurs in pegmatite greisen or altered granite, and is generally in the form of coarse granules, although large masses of fine grains of the mineral are found between the schist and porphyry. Ore has averaged 1 per cent of metallic tin, and concentrates have ranged from 62.5 to 65 per cent of metallic tin.

1021. THOMAS, JOSIAH, with notes by J. S. CHILDS. The Harney Peak tin deposits.

Eng. Mg. Journ., Vol. 54, 1892, New York, pp. 512-514, 536.

Reprint: Mg. Journ. Railw. Comm. Gaz., Vol. 62, 1892, London, pp. 1182-1183.

Editorial: pp. 1190-1191.

Lodes occur in slate and schists surrounding Harney Peak, which is of granite. In almost all instances lodes or ledges are either vertical or dipping away from the granite. Lodes small but continuous, being from 1 to 3 feet wide composed principally of quartz. Gives description of various workings. No theory as to origin of deposits. Ore will yield 40 pounds of black tin per ton, giving 73 per cent metallic tin.

1022. THURLOW, LORD. The Harney Peak tin properties.

Mg. Journ. Railw. Comm. Gaz., Vol. 62, 1892, London, p. 907.

Extracts from a report made after visiting deposits, the object of which was to ascertain the amount of development done, inspect machinery, ascertain probable date at which tin production on a commercial scale might begin. Report does not give geographical or geological description.

1023. TODD, J. E. Geology of South Dakota. Tin.

South Dakota Geol. Surv. Bull No. 1, a Preliminary Report on the Geology of South Dakota, 1895, Sioux Falls, pp. 149-150, pls. 5, figs. 2, map 1.

Analyses of tin ore from veins contains 74.5 to 76.7 per cent tin which is higher than that from other prominent localities.

SOUTH DAKOTA (Continued)

ULKE, TITUS. A contribution to the geology of Dakota tin mines.

Eng. Mg. Journ., Vol. 53, 1892, New York, p. 547.

Thinks granitic dikes are of igneous origin but says they show little metamorphosing action on the schists. Mentions apatite, triplite, heterosite, triphylite, almandite, wolframite, beryl, sphalerite, cuprocassiterite, graphite. Calls attention to absence of fluorine minerals, hornblende, molybdenite, etc. Tin segregated in pockets or zones with intervening barren places.—L. C. Graton.

———. *See* No. 1646.

VINCENT, M. C. The tin deposits of Dakota.

Mg. Journ. Railw. Comm. Gaz., Vol. 58, 1888, London, pp. 971-972.

Extracts from a report on the Black Hills deposits. Tin occurs in granite in two distinct forms or types, "1st of the approximately circular or columnar form, where the granite mass stands almost vertical, and 2d, those filling a long narrow, longitudinal rent or fissure." 83 assays of black tin made by author averaged 74.31 per cent metallic tin. Absence of iron, lead, arsenic, and zinc. Description of mines. Author believes that mines will prove productive.

SPAIN

ANONYMOUS. L'industrie minérale de l'Espagne en 1893.

Rev. Univ. Mines Mét. Trav. Publ. Sci. Arts Appl. Indust., ser. 3, Vol. 26, 1894, Paris and Liége, p. 236.

The provinces of Orense, Pontevedra and Coruña are mentioned as tin producing, while that of Salamanca has ceased since 1894 on account of heavy taxation.

———. Tin in Spain and Portugal.

Min. Ind. for 1897, Vol. 6, 1898, New York and London, p. 641.

According to report of U. S. Consul at Corunna, tin ore has been worked considerably in Galicia during late years. There is a wide tin-bearing belt, which runs from Zamora through a corner of Portugal, through the Province of Orense and from there through Santiago up to the coast, nearly 250 miles.

ECK, RICHARD. *See* No. 1299.

OBLASE, WILLIAM COPELAND. Tin mining in Spain, past and present.

London (1898), pp. 40, illus. 10, map 1.

Gives a historical sketch and generalized account of tin mining in Spain, with a few references to Portugal. Geology is lightly skimmed. Thinks there is a large quantity of ore in Spain carrying 2½ per cent tin.

WN, A. SELWYN. *See* Nos. 1307 and 1308.

DERÓN, D. SALVADOR. La cassiterite y los filones estanniferos de estra Peninsula.

Bol. Soc. esp. Hist. Nat., Vol. 1, 1901, Madrid, pp. 231-240.

Digest: Geol. Centr., Vol. 2, 1902, Leipzig, p. 357.

L'auteur donne la bibliographie concernant les filons stannifères depuis 1847 à 1900, t examine les régions stannifères de la Péninsule, qui se groupent en une région rincipale située dans la Galice et passe en Portugal, et en gisements épars, de peu 'importance.—Choffat.

RT, ALBERT F. Impressions of Spain.

1903 (?) London.

Reviewed: Austr. Mg. Stand., Vol. 31, 1904, Sydney and Melbourne, p. 87.

Tin is mentioned as among the resources of Spain, yet "considerably untouched" ot available to the authors.

SPAIN (Continued)

1031. COQUEBERT, CH. Mémoire sur les mines d'Espagne.
Journ. Mines, No. 29, Vol. 5, 1796-1797, Paris, p. 407.

1031a. CORNIDE, JOSEPH D. Memoria sobre las Minas de Galicia y otras producciones del reyno mineral dirigada al Sr. D. Miguel Bañuelos, su Intendente General.
The work is a folio MS. of 18 pages, in the Biblioteca de la Real Academia de la Historia, Madrid.
Noted by W. C. Borlase in Tin Mining in Spain, Past and Present (1898), page 37.

1031b. DE CORTÁZAR, DANIEL. Datos Geologico. Mineros de la Provincias de Zamora y Orense.
Bol. Com. Mapa Geol. España, Vol. 1, 1874, Madrid, pp. 6, 14.

D'ACHIARDI, ANTONIO. *See* No. 1313.

FAWNS, SYDNEY. *See* No. 1320.

FUCHS, E., and LAUNAY, L. DE. *See* No. 1323.

1032. GARCÍA, MANUEL. Nota acerca de algunos filones estanníferos de la Provincia de Salamanca.
Bol. Com. Mapa Geol. España, Vol. 3, 1876, Madrid, pp. 91-95.

1033. GARLAND, JOSEPH. On certain tin deposits in Galicia, Spain.
56th Ann. Rep. Roy. Cornwall Polyt. Soc. 1888, Falmouth, pp. 54-57, figs. 3.
No systematic mining or quarrying has been attempted on these tin deposits. The work has been carried on mainly by agricultural laborers and women and children. The ore occurs in a strata of soil, clay, decomposed shale, sand and pebbles. The soft character of this tin ground would admit of cheap working, the only essential dressing machinery being perhaps washing and sizing trommels and automatic jigs. There can be no doubt that these tin deposits would pay to work on a considerable scale.

1034. GIL Y MAESTRE, AMALIO. Descripción, física, geológica y minera de la Provincia de Salamanca.
Mem. Com. Mapa Geol. España, 1880, Madrid, pp. 255-261.
At Martinamor veins are in gneiss, at other places they are in Silurian slates, more or less dark, gray, greenish, brown, blue. Veins are principally quartz, carrying tourmaline, wolframite, some arsenopyrite and copper sulphide. Veins running in different directions are without noticeable difference in mineralization. Some greisen dikes carry up to 9 per cent tin. One vein at Terubias gave 25 kilos per cubic metre of 40 per cent tin ore. This vein is 1600 metres long. Some 60 per cent ore was obtained.

1035. HARMONY, JULIO. The mines of Galicia.
U. S. Consular Reports, No. 197, Vol. 53, Feb. 1897, Washington, D. C., p. 312. (House of Representatives' Document No. 164, pt. 3, 54th Congress, 2d Session.)

1035a. LA ESCOSURA, LUIS DE. Descripción de las minas de la Provincia de Zamora, 1846.
Not available to the authors.

LOCK, C. G. WARNFORD. *See* No. 1338.

LOUIS, HENRY. *See* No. 1340.

SPAIN (Continued)

)36. LOZANO, R. SANCHEZ. Nota referente á varios yacimientos de estaña de la provincia de Pontevedra.

Bol. Com. Mapa Geol. España, Vol. 28, 1907, Madrid, pp. 14-25.

)37. MALLADA, L. Explicación del mapa geológico de España.

Mem. Com. Mapa Geol. España, Vol. 1, 1895, Madrid, pp. 173-174, 545-547.

)38. MASSART, ALFRED. Gisements métallifères du district de Carthagène (Espagne).

Ann. Soc. géol. Belg., Vol. 2, 1875, Liége, pp. 58-107, colored plate 1.

Wood tin is found in small veins in a schist. The veins lie in the planes of schistosity at the San Isidoro, Marinera and Superior segunda mines. In the last, the vein is in lenticular spongy masses of quartz with some barytes and galena.

)39. PACHECO, HERNANDEZ E. Los filones estanníferos de Cáceres y su comparación con los de otras regiones.

Bol. Soc. esp. Hist. Nat., Vol. 2, 1902, Madrid, pp. 72-81.

Digest: Geol. Centr. Vol. 3, 1903, Leipzig, p. 73.

L'auteur decrit quelques petits filons de cassitérite recemment découverts dans les schistes siluriens de la Montana de Caceres, à 5 kilom. de cette capitale. La cassitérite en cristaux simples ou maclés (bec d'étain) est incluse dans un quartz laité, accompagnée d'un fluorure aluminique hydraté que l'auteur rapporte à la fluéllite. Dans les bords des filons il y a une zône constituée par des lamelles de nacrite et souvent d'une bande blanche ou veodâtre de lithomarge qui forme la gangue. Un filon est constituée seulement par du quartz et phosphorite.

Ces la première fois que la fluéllite est mentionnée en masse considérable.

Ces filons différent de tous les autres filons stannifères connus en Espagne, étant depourvus de roches éruptives dans leur voisinage. D'aprés l'auteur ces filons de Cáceres doivent être envisayés comme alumineux plutôt que comme stannifères.—S. Calderon.

PHILLIPS, J. A., and LOUIS, H. *See* No. 1350.

)40. PILZ, R. Die Erzlagerstätten von Cartagena in Spanier.

Zeitschr. prakt. Geol., Jahr. 16, 1908, Berlin, pp. 177-190, figs. 31-37.

The principal ore deposits carry argentiferous galena, zinc blende, and pyrite, with secondary cassiterite and limonite; others carry cassiterite and barite.

The cassiterite is thought to be secondary after stannite.

)41. PUIG Y LARRAZ, D. GABRIEL. Descripción fisica y geológica de la Provincia de Zamora.

Mem. Com. Mapa Geol. España, 1883, Madrid, pp. 411-437.

Tin occurs generally in quartz, sometimes in granite or granulite. Is also found in alluvial deposits. Occurs rather widely. Found in zone of contact of crystalline schists and granite rocks, and is also found in both rocks. Much tourmaline. Some chalcopyrite, cut by veins of lead-antimony sulphides. Rarely found far from eruptives. Veins usually 25 to 50 centimetres wide, rarely 1 metre wide.

)42. SCHUBARTH, E. L. Ueber das Vorkommen von Zinn in Spanien.

Ann. Physik. Chem., Vol. 86, 1852, Leipzig, p. 600.

Digest: Neues Jahrb. Min., 1853, Stuttgart, p. 460.

)43. SCHULZ, GUILLAUME, and PAILLETTE, ADRIEN. Notice sur une pyrite stannifère (ballestérosite) et sur quelques gisements d'étain en Espagne.

Bull. Soc. géol. France, ser. 2, Vol. 7, 1850, Paris, pp. 16-25.

Abstracts: Neues Jahrb. Min., 1850, Stuttgart, p. 710 and 1851, p. 350; Berg. Hütt. Zeit., Vol. 10, 1851, Leipzig, p. 352.

SPAIN (Continued)

1043a. SCHULZ, DER GEMEINDE. Descripción geognostica de Reino de Galicia, acompañada de un mapa petrographico de este pais.

1835, Madrid, pp. 62, pls. 2.

Abstract: Bull. Soc. géol. France, t. 4, 1833, Paris, pp. 416-418.

The original is not available to the writer. The abstract which is in the form of a letter written to the Société Géologique de France gives a sketch of the geology of the tin-bearing part of northwestern Spain.

1044. THOMAS, CHARLES. Some Spanish tin deposits.

Trans. Mg. Ass. Inst. Cornwall, Vol. 2, 1888-1889, Camborne, pp. 66-72.

Short description of stream tin placers near Ribadavia, Province of Orense, in Galicia.

SWAZILAND

1045. ANONYMOUS. Tin in South Africa.

Min. Ind. for 1896, Vol. 5, 1897, New York and London, p. 329.

Extract from communication of S. Ryan. Describes geology of tin district of Swaziland.

1046. ———. Tin in Swaziland.

Min. Ind. for 1897, Vol. 6, 1898, New York and London, p. 644.

According to British Consular Report No. 1896, Annual series, the Ryan Tin Company did a good deal of work in 1896, and in the first six months produced upward of 200 tons of black tin. Machinery has been erected. Great drawback to working tin and coal deposits of territory is lack of transportation facilities.

1047. ———. Tin in South Africa.

Austr. Mg. Stand., Vol. 29, 1902, Sydney and Melbourne, p. 699.

"'S. A. Mines' considers that it is not improbable that South Africa may in the near future, become one of the important tin producing countries of the world." Description of deposits in Swaziland, near Embabaan, and new discoveries in Cape Colony, most important of which has been made on Knil's River.

1047a. ———. Alluvial tin in Swaziland.

South African Mg. Journ., Vol. 7, pt. 2, 1909, Johannesburg, pp. 115-116.

Notes from Annual report of the manager of Swaziland Tin, Ltd., which, describing various creeks on which alluvial tin occurs, points out new fields for prospecting, and explains a scheme for hydraulicking or sluicing all the hill creeks.

BECK, RICHARD. *See* No. 1299.

1048. HAHN, P. D. Presidential address.

Rep. South African Ass. Adv. Sci. 1903, Cape Town, p. 43.

"Another interesting problem for research for the student of mineral chemistry is furnished at the tin ore deposits at Embabaan in Swaziland. Together with tin ore occur at this locality extraordinarily rare and most interesting minerals, such as aeschynite, euxenite, fergusonite and monazite."

1049. HAMPTON, J. H. On the occurrence of tin.

Trans. Geol. Soc. South Africa, Vol. 4, 1900, Johannesburg, pp. 37-40.

The tin deposits of Malay Peninsula, Mt. Bischoff and Swaziland, near Embickelweni are treated in a brief manner. The author visited Swaziland in 1889-1890, and at that time received the impression from appearance of the country that tin existed in lode or alluvial form.

SWAZILAND (Continued)

1050. JORISSEN, E. Notes on some intrusive granites in the Transvaal, the Orange River colony and in Swaziland.

Trans. Geol. Soc. South Africa, Vol. 7, 1905, Johannesburg, p. 158. Read December 12, 1904.

In East Swaziland near Embabaan, cassiterite occurs in gneiss at the contact of a narrow vein of pegmatite. Much biotite present.

LOCK, C. G. WARNFORD. *See* No. 1338.

1051. LYBURN, JOHN. Mining and minerals in the Transvaal and Swaziland.

Sci. Proc. Roy. Dublin Soc., n. s., Vol. 9, 1899-1902, Dublin, p. 20.

"Alluvial cassiterite occurs in the Embabaan, Swaziland. The mother lode has not yet been discovered."

1052. MOLENGRAAFF, G. A. F. Tinstone in Swaziland. Report of the State geologist of the South African Republic for the year 1897.

Trans. Geol. Soc. South Africa, Vol. 4, pt. 6, 1898, Johannesburg, pp. 141-144.

Abstract: Zeitschr. prakt. Geol., Vol. 8, 1900, Berlin, pp. 146-147.

Digest: Neues Jahrb. Min., 1900, I (Ref.), Stuttgart, pp. 263-265.

The Ryan tin works near Embabaan in the northeast part of Swaziland, are the only important deposits of the country. SnO_2 occurs in pegmatite dikes cutting granite near the contact of the latter with various schists, and in placers derived from the dikes, accompanied by corundum, monazite, magnetite, etc. Crystals of cassiterite are so distorted as to appear monoclinic. Does not think the outlook good for very large placers.

1053. NEWLAND, D. H. Tin in South Africa.

Min. Ind. for 1903, Vol. 12, 1904, New York and London, p. 332.

Discovery of lode tin in the Transvaal was reported in August, 1903. Principal formation is granite, which is overlain in places by schistose rocks, and the tin-bearing veins occur near the contact. Three lodes have been discovered.

1054. PRIOR, G. L. Minerals from Swaziland: niobates and titanates of the rare earths, chemically allied to euxenite and fergusonite; cassiterite, monazite, etc. The "Aeschynite from Hitterö."

Min. Mag. Journ. Min. Soc., Vol. 12, 1899, London, pp. 96-101.

Digest: Neues Jahrb. Min., 1901, I (Ref.), Stuttgart, p. 31.

1055. RYAN, —. Swaziland tin fields.

Proc. Chem. Met. Soc. South Africa, Vol. 2, 1897, Johannesburg, pp. 16-18.

Tin fields along Embabaan River on eastern slope of Drakensberg Mountains, 15 miles from Transvaal border were discovered by Mr. Ryan in 1891. Geology: "Granite boss flanked by metamorphic rocks intersected by elvan dykes, diorite and rhyolite." From January, 1894, to June, 1896, exported about 600 tons of ore. Deposits mostly alluvial, average thickness of beds 4½ feet, though on Lower Embabaan and Usutu rivers, beds of considerable thickness are being found.

1056. SMUTS, —. Report on the trade, commerce and general condition of Swaziland.

British Consular Rep., No. 1996, 1897, London, p. 3.

The Ryan Tin Company has done a good deal of work during 1896. First 6 months, by sluicing process, upwards of 200 tons of tin were produced, valued at about £45 sterling per ton. During latter half of year, about 20,000 tons of tin-bearing gravel was exposed. Tin reefs have been discovered, and further prospecting is being undertaken.

SWEDEN

DAVIES, D. C. *See* No. 1317.

TASMANIA

1057. ANONYMOUS. Report on Mount Bischoff tin mines, Tasmania, with topographical sketch map.

1874, Launceston, 8vo., pp. 5.
Not available to the authors.

1058. ———. Tin from Tasmania.

Iron, Vol. 6, n. s., 1875, London, p. 42.
Announcing the first shipment of tin to England. Assayed 99.96 pure tin, superior to Australian tin. Shipment for the year probably not over 300 tons.

1059. ———. Tasmanian tin.

Iron, Vol. 6, n. s., 1875, London, p. 711.
A short review of a report by Mr. Newman, on the Mount Bischoff, Cummings and Henry, Stanhope and Waratah mines.

1060. ———. Tin fields of Tasmania.

Mg. World, Eng. Rec., Vol. 14, 1878, London, p. 649.
Not available to the authors.

1061. ———. The greatest tin mine in the Southern Hemisphere.

Austr. Mg. Stand. September, 1896, Sydney and Melbourne.
Description, with illustration, of the Mount Bischoff Mine, Tasmania.
Not available to the authors.

1062. ———. Tin in Tasmania.

Min. Ind. for 1898, Vol. 7, 1899, New York and London, p. 712.
Mt. Bischoff continued to be largest producer. Tin ore is also found in the Ringarooma Valley at Branxholm, Derby, Moorina, Pioneer and Mt. Cameron, where the Brothers' Home, Briseis, Brothers' Home No. 1, Arba and Armuz mines are situated. The east coast deposits have been proved to be extensive, and a discovery of tin ore on the Great Mussel Roe River has recently been reported.

1063. ———. Mt. Bischoff tin mine.

Mg. Sci. Press, Vol. 81, 1900, San Francisco, p. 431.
Note stating Mt. Bischoff tin mine contains perhaps most remarkable tin deposit in the world. Average grade of ore is 3 per cent. The concentrates average about 70 per cent tin, yielding an average of 68 per cent in smelting.

1064. ———. Tin in Tasmania.

Min. Ind. for 1899, Vol. 8, 1900, New York and London, pp. 622-623.
The working expenses of Mt. Bischoff mine given. Gives a short account of the Briseis mine. A new discovery of tin at Renison Bell mine at North Dundas, on the west coast is reported. Tin was found in schist near Mt. Lyell.

1065. ———. Tin in Tasmania.

Min. Ind. for 1900, Vol. 9, 1901, New York and London, pp. 638.
Tasmania is largest producer of tin in Australia, output for 1899 amounting to 3281 long tons of ore, valued at £270,864. A large part of the ore is obtained from alluvial deposits, the lodes, except at Mt. Bischoff mine, have received little attention.

TASMANIA (Continued)

1066. ———. Tin mining in Tasmania.

Austr. Mg. Stand., Vol. 20, August 15, 1901, Sydney and Melbourne.

"Describes the alluvial deposits at Mt. Bischoff."

Not available to the authors.

1067. ———. Tin in Tasmania.

Min. Ind. for 1901, Vol. 10, 1902, New York and London, p. 640.

The output of tin ore was less in 1901 than in the preceding year. This unexpected result being due principally to the poorer quality of the ore raised from the Mt. Bischoff mines, the most productive in the State.

1068. ———. Heemskirk (T.), tin find.

Austr. Mg. Stand., Vol. 21, 1902, Sydney and Melbourne, p. 665.

An account of a "rich find of lode tin on the Orient farm," about nine miles from Zeehan T. Outlook is said to be good.

1069. ———. Tin in Tasmania.

Min. Ind. for 1902, Vol. 2, 1903, New York and London, p. 594.

Mt. Bischoff Tin Mining Company in the last six months of the fiscal year crushed 50,044 tons of stone for a yield of 636 tons of concentrates. The cost of mining, crushing and dressing was 5s. 7d. per ton. During year the company earned profits of £62,612 and distributed dividends of £54,000.

1070. ———. The Pioneer tin mine, Tasmania.

Austr. Mg. Stand., Vol. 29, 1903, Sydney and Melbourne, pp. 13-15, 49-50. Serial. Illus.

Description of the deposits of northeast Tasmania, with some details of the history and difficulties in working (from a financial standpoint), and methods and machinery used.

1071. ———. Northeast Dundas [Tasmania] tin.

Austr. Mg. Stand., Vol. 31, 1904, Sydney and Melbourne, pp. 810-811, 1300 words.

"Describes the deposits of this district, and work done in developing."

1072. ———. Mining in Tasmania.

Mg. Journ. Railw. Comm. Gaz., Vol. 76, 1904, London, p. 27, 1000 words.

Digest from Mg. Mag., Vol. 10, 1904, New York, p. 154.

"Recent news of the condition of Tasmanian mines; gold, tin and copper, with estimates of reserves at Mount Lyell."

1073. ———. Tasmania tin fields.

Min. Ind. for 1904, Vol. 13, 1905, New York and London, pp. 392-393.

"The cassiterite of Mt. Bischoff is associated with topaz, both crystalline and amorphous, in large dikes of an acidic porphyritic rock penetrating slate and sandstone. The topaz has replaced feldspar, the rock containing no alkali, and consisting practically of quartz and topaz. It is comparable to the Saxon 'sneckenstein,' a topaz quartz-porphyry."

Gives a résumé of tin mining in Tasmania during 1904.

BECK, RICHARD. *See* No. 1299.

1074. BENEDICT, WM. DE L. Tin in Tasmania.

Min. Ind. for 1892, Vol. 1, 1893, New York, pp. 444-445.

"Tin ore was found in Tasmania at an early date in the history of the colony, but it was not until 1872 that the great Mt. Bischoff property was discovered. . . . . The tin is found in what is termed euritic porphyry and the most productive portions of the deposit are situated close to the porphyry and slate."

The next district in importance is Ringarooma. The deposits at this place appear to be the bed of an ancient river running nearly north and south and are covered by a crust of basalt.

TASMANIA (Continued)

1075. BONWICK, JAMES. Tasmanian tin.

Mg. Journ. Railw. Comm. Gaz., Vol. 44, 1874, London, p. 331.

Brief description of the lode and alluvial tin deposits at Mount Bischoff.

BROWN, A. SELWYN. *See* Nos. 1307 and 1308.

1076. CLARK, DONALD. Tasmanian mining and metallurgy.

Austr. Mg. Stand., Vol. 29, from March 12 to April 16, 1903, Sydney and Melbourne, pp. 362-363, 398-400, 432-435, 462-463, 496-498, 528-530.

A series of articles which deal with tin mining and smelting in Tasmania.

1076a. ———. Australian mining and metallurgy.

1904, Melbourne, Sydney and Perth, pp. 185-228, pls. 7, figs. 13.

Describes the geology, mining methods and milling methods at the Mt. Bischoff, Anchor, Cornwall, and Maynes tin mines. All are located in Tasmania.

1077. COGHLAN, T. A. Tin.

A statistical account of Australia and New Zealand, 1903-1904, p. 934.

1078. CONDER, HARTWELL. Tin mining in Tasmania.

Mg. Journ. Railw. Comm. Gaz., Vol. 78, 1905, London, p. 350, 1800 words.

Reviews briefly the history, and describes present conditions of tin mining in Tasmania.

1078a. ———. Stanley River tin field.

Austr. Mg. Stand., Vol. 41, 1909, Sydney and Melbourne, p. 637, map 1.

The Stanley River tin field is 20 miles north of Zeehan, Tasmania, on the west coast. A road has just been finished which makes it accessible. Country rocks are quartzites and clay-stones cut by porphyritic granite. Porphyritic feldspars in many places have been replaced by green tourmaline and this, in turn, partly replaced by SnO_2. One tourmaline-quartz lode 16 feet wide carries 2 per cent tin. Boulders in river are probably worth working. Wolframite and monazite form impurities in the stream tin. Notes the occurrence of pyrrhotite carrying a "small proportion of" Cu and Ni." Map gives geology, claims and owners.

Gives some objections to the government's system of renting claims.

1079. COUNSEL, E. A., Surveyor General. Sketch map, general geological features of Tasmania.

Government Printing Department, January, 1898, Hobart. Lithograph, hachured. 1 inch=15 miles.

Geological features in colors. Gold, tin, silver and lead, bismuth, antimony, copper, iron, and coal deposits shown by characters.

D'ACHIARDI, ANTONIO. *See* No. 1313.

1080. DAVEY, JOHN. Mount Bischoff tin mines.

Rep. Proc. Min. Ass. Cornwall and Devon, for 1881 (1882), Truro, pp. 8-10.

Extract from a letter dated May, 1881. Geographical description of the tin-bearing country; manner of occurrence and working; percentage of yield; loss of ore in dressing.

DAVIES, D. C. *See* No. 1317.

1081. DIJK, P. VAN. Tinontginning in Tasmanië.

Jaarb. Mijnw. Ned. Oost-Indië, 1882, II, Amsterdam, pp. 91-101.

1082. ———. Tinontginning in Tasmanië.

Jaarb. Mijnw. Ned. Oost-Indië, 1883, II, Amsterdam, pp. 109-114.

TASMANIA (Continued)

ENGLISH, A. G. *See* No. 50.

1083. FAWNS, SYDNEY. Notes on the Mount Bischoff tin mine.
Trans. Inst. Mg. Met., Vol. 14, 1905, London, pp. 221-228. Discussion, pp. 229-243. Contributed remarks, pp. 244-249.
Abstracts: Mg. Journ. Railw. Comm. Gaz., Vol. 77, 1905, London, p. 62. Eng. Mg. Journ., Vol. 79, 1905, New York, pp. 470-471.
Digest: Min. Mag., Vol. 11, 1905, New York, pp. 355-357.
Gives short history of mine; says tin occurs in veins and replacement deposits in topaz porphyry. Briefly describes the Queen and North Valley lodes, Don and Stanhope sections, the White, Brown, Slaughter-yard, and Alluvial North faces. Gives a list of minerals and rocks occurring with the deposits. Most of the paper is devoted to the working system and costs.

1084. ———. Mount Bischoff and Dolcoath.
Mg. Journ. Railw. Comm. Gaz., Vol. 77, 1905, London, p. 297.
A letter comparing some of the modes of working.

———. *See* No. 1320.

1085. FIRCKS, F. W. VON. Die Zinnerzlagerstätten des Mt. Bischoff in Tasmanien.
Zeitschr. deutsch. geol. Ges., Vol. 51, 1899, Berlin, pp. 431-434, pls. 27-28.
Digest: Neues Jahrb. Min., 1901, I (Ref.), Stuttgart, pp. 423-425.

1086. GOULD, CHAS. A note upon a recent discovery of tin ore in Tasmania.
Quart. Journ. Geol. Soc. London, Vol. 31, 1875, London, pp. 109-110.
Digest: Geol. Rec. for 1875, London, p. 242.
"Ore is not 'stream tin' in true sense of the word; but the disintegration of veins and strings running through the porphyritic rock, of which the mount is composed, gives rise to a shallow surface-drift from which the tin-ore is procured. Lodes in adjacent slaty rocks contain antimony and zinc blende." (Mt. Bischoff,)

1087. GRANT, H. Tasmanian tin deposits.
Austr. Mg. Stand., November 17, 1898, Sydney and Melbourne.
"The history of the tin mining on the Blue Tier formations."
Not available to the authors.

1088. ———. The Blue Tier [Tasmania] tin dykes.
Austr. Mg. Stand., Vol. 17, 1900, Sydney, p. 151.
"Information concerning this important discovery and the working of the deposits."

1089. ———. Tasmanian tin fields. (I) The Blue Tier, East Coast, The Moon and Lottah claims. (II) The Echo Mine.
Austr. Mg. Stand., Vol. 18, 1900, Sydney, pp. 277-278, 551-552.
Description of Blue Tier and Echo mines on the East Coast; their possibilities, difficulties encountered and outlook.

1090. ———. Mining in Eastern Tasmania.
Austr. Mg. Stand. Vol. 19, 1901, Sydney and Melbourne, pp. 667-668, 3500 words.
"An account of the tin mining, the deposits and their development."

1091. ———. Brookstead tin field.
Austr. Mg. Stand., Vol. 35, 1906, Sydney and Melbourne, 2000 words.
"A review of the development of the Brookstead lode, in northeastern Tasmania, showing the richness of the field, and the importance of thorough prospecting."

TASMANIA (Continued)

1092. GREGORY, J. W. The geological plans of some Australian mining fields.

Science Progress, No. 1, 1906, London, pp. 117-136.

Describes among others the Mt. Bischoff mine, the character of the ore in the different faces, and the metamorphism of the rocks.

1093. GRODDECK, A. VON. Zur Kenntniss der Zinnerzlagerstätte des Mount Bischoff in Tasmanien.

Zeitschr. deutsch. geol. Ges., Vol. 36, 1884, Berlin, pp. 642-652. Translated by Thureau, G. in Pap. Proc. Roy. Soc. Tasmania, for 1885 [1886], Hobart, pp. 388-394.

Reviewed: Neues Jahrb. Min., 1885, II (Ref.), Stuttgart, pp. 91-92.

Continuation of original article, Zeitschr. deutsch. geol. Ges., Vol. 38, 1886, Berlin, pp. 370-375. Translated by Wolfhagen in Pap. Proc. Roy. Soc. Tasmania for 1886 [1887], Hobart, pp. 189-193.

Continuation of original article. Zeitschr. deutsch. geol. Ges., Vol. 39, 1887, Berlin, pp. 78-87.

Reviewed in Neues Jahrb. Min., 1888, 1 (Ref.) Stuttgart, pp. 86-87.

1094. HAMPTON, J. On the occurrence of tin.

Trans. Geol. Soc. South Africa, Vol. 4, 1899, Johannesburg, pp. 37-40.

The tin mine at Mt. Bischoff, discovered 1872, was visited by author in 1883. Tin bearing rock was 100 feet wide. Largest tin deposit yet discovered. It is at considerable elevation from the sea, where neither pumping nor hauling machinery are required.

1095. HARCOURT-SMITH, J. Report on the Shepherd and Murphy's tin mine, Bell Mount.

Rep. Secr. Min., Tasmania, for 1896-1897 (1897), Hobart, pp. lv-lvi.

This property is situated 22 miles southwest from Sheffield, at an elevation of about 2000 feet above sea level. Lodes 1 to 6 are described, and the work done, with results obtained. The company will attempt to separate tungsten and bismuth as well as the tin contents.

See also No. 1148.

1095a. ———. The mineral industry of Tasmania. *See* Tasmania, Government Geologist, No. 1134.

1096. HUNT, JOHN. Mount Bischoff tin mines, Tasmania.

Mg. Journ. Railw. Comm. Gaz., Vol. 44, 1874, London, p. 207.

Very general; unimportant.

1097. ———. On mining in Tasmania.

Mg. Journ. Railw. Comm. Gaz., Vol. 45, 1875, London, pp. 539-540.

Thinks the deposit of tin at Mount Bischoff is not of volcanic origin. Believes the greater part of alluvial tin is derived from decomposition of granitic rocks.

1098. IRELAND, MARK. A method of timbering at the Mt. Rex tin mine, Ben Lomond, Tasmania.

Trans. Austr. Inst. Mg. Eng., Vol. 10, 1905, Melbourne, pp. 263-264.

Short article giving method of timbering which is of such a character that no blasting, however heavy, can injure it.

1099. JOHNSTON, R. W. Geology of Tasmania.

1888, Hobart, pp. 22-29.

Description of tin lodes, mode of occurrence, distribution, discovery and derivation. Age of superficial gravels discussed.

TASMANIA (Continued)

1100. KAYSER, H. W. F. Tin mining in Tasmania.

Trans. Fed. Inst. Mg. Eng., Vol. 13, 1897, London and Newcastle-upon-Tyne, pp. 570-582, pl. 24, map (1 inch=1125 feet).

Abstract: Ind. and Iron, June 11, 1897, London.

A review of the mining industry of Tasmania. Discovery, difficulties and results of early tin mining. The writer was connected with Mt. Bischoff Mining Company more than 21 years, and that mine is treated at some length.

1101. ———. The Mount Bischoff tin mining company, registered.

Ann. Rep. School Mines Zeehan, Tasmania, for 1905, pp. 96-98, pls. 2.

Gives very briefly a history of the mine, its geology and method of working. Also description of milling plant, and the profits paid.

1102. KAYSER, H. W., and PROVIS, RICHARD. Mt. Bischoff tin mine, Tasmania.

Proc. Inst. Civ. Eng., Vol. 123, 1896, London, pp. 377-387, figs. 8. Abridged.

Ore in large veins averages 2 to 3 per cent cassiterite. Cost of mining and delivering ore to dressing works is 3s. 2½d. or 80 cents per ton of 2240 pounds. Cost of dressing is 1s. 1½d., or say 27 cents per ton, about 6000 long tons of material being treated per month. First grade concentrates average 70.5 per cent tin. Second grade concentrates average 65 per cent tin; does not pay to dress cleaner than this.

1103. KLOCKMANN, F. Ueber den Antheil von Groddeck's an der Deutung der Zinnerzlagerstätte des Mt. Bischoff.

Zeitschr. deutsch geol. Ges., Vol. 52, 1900, Berlin, pp. 167-168.

Digest: Neues Jahr. Min., 1903, I (Ref.), Stuttgart, p. 91.

Digest: Geol. Centr. Vol. I, 1901, Leipzig, p. 228.

W. von Fricks äusserte in einem Aufsatze über die Zinnerzlagerstätten des Mt. Bischoff in Tasmanien (Zeitschr. deutsch. geol. Ges., Vol. 51, 1899, Berlin, p. 431), dass v. Groddeck die Zinnführenden Gesteine dieses Berges für ursprünglich und nicht für pseudomorph erklärt habe. Verf. weist dagegen aus zwei Nachträgen v. Groddeck's, Arbeiten, die v. Fricks anscheinend übersehen hat, nach, dass v. Gr. bereits sich mit aller Bestimmtheit für die pseudomorphe Entstehung der Erzlagerstätten des Mt. Bischoff ausgesprochen hat.

LATTA, GEO. J. *See* No. 1517.

1104. LEWIS, JAMES B. The New Brothers' Home No. 1 Tin Mining Company, Derby.

Rep. Secr. for Mines, Tasmania, 1902-1903 (1903), Hobart, pp. XCIX-CII, pls. 2.

Abstract: Eng. Mg. Journ., Vol. 75, 1903, New York, pp. 815-816.

A description of the manner in which overburden is removed.

1105. ———. The Anchor tin mine, Tasmania.

Eng. Mg. Journ., Vol. 81, 1906, New York, p. 1249.

A communication giving a brief analysis of working cost for low grade tin ore. They are working profitably on a yield of 5 pounds black tin per ton, or 3.5 pounds metallic tin.

1106. ———. Tin mining in Tasmania.

Eng. Mg. Journ., Vol. 85, 1908, New York, pp. 485-489; pls. 3, map 1.

Commercial conditions at the Mount Bischoff, Heemskirk, Brookstead, Avoca, Briseis and Pioneer mines are described.

Gives a few notes upon dredging for tin in Tasmania, and refers to tin mining operations in the Gladstone District. The article has evidently been edited and abridged, not altogether to its advantage.

LOCK, C. G. WARNFORD. *See* No. 1338.

TASMANIA (Continued)

LOUIS, HENRY. *See* No. 1340.

———. *See* No. 1525.

1107. MEREDITH, C. Verbal remarks on specimens of tin ore from Mount Bischoff, Tasmania.

Pap. Proc. Roy. Soc. Tasmania [monthly notices—June], 1873 [1874], Hobart, p. 21.

Not available to the authors.

1107a. MILLEN, J. D. Mount Bischoff tin mining company, Tasmania.

Austr. Mg. Stand., Vol. 41, Nos. 1061, 1062, 1900, Sydney and Melbourne, pp. 264, 293-294. Illus. (In section of Electrical Record, Vol. 19.)

"A description of the hydro-electric power plant, its equipment and operation."

———. *See* No. 1535.

1108. MONTGOMERY, ALEX. The Blue Tier tin field.

Geol. Surv. Rep. Tasmania, November, 1889, Hobart.

Not available to the authors.

1109. ———. The tin mines at the Blue Tier, county of Dorset.

Geol. Surv. Rep. Tasmania, January, 1903, Hobart.

Not available to the authors.

1110. MONTGOMERY, ALEXANDER. The mineral resources of Tasmania.

1894, Hobart, pp. 3-28.

Tasmania is the third largest tin producer in the world, the value of tin ore raised being greater than all the other minerals of Tasmania put together. The tin deposits may be grouped as : (1) Alluvial. (2) Lodes or veins. (3) Impregnations or stockworks. The veins occur in districts which are composed almost entirely of granite or of sedimentary rocks penetrated by quartz-porphyry dikes. Vein or lode mining has not yet been very successful in Tasmania. Stockworks or impregnations of tin ore, found in several localities are likely to be of very great importance. Mt. Bischoff mine shows a curious combination of all the different types of tin deposits.

1111. ———. The mineral industry of Tasmania.

Eng. Mg. Journ., Vol. 57, 1894, New York, p. 389.

Good general description of tin deposits. Principal alluvial workings in northeast part of Tasmania, along Ringarooma and George's rivers and their tributaries. Deposits of different ages, miocene to recent. Some of older drifts covered by basalt and worked by underground mining, but most is obtained from shallow workings by ground sluicing. The ore which has been easily worked is about all taken out. Hydraulicking larger and poorer deposits. Thinks they will last for a century.

1112. ———. Report on the progress of the mineral fields in the neighborhood of Zeehan, viz.: Mackintosh River, Mount Black, Mount Read, Mount Dundas, Mount Zeehan, Stanley River and Mount Heemskirk.

Rep. Secr. Min. Journ. and Printed Papers of the Parliament of Tasmania. Vol. 38, 1895, Hobart, pp. VII-LI.

Not available to the authors.

1113. ———. The useful minerals of Tasmania.

Trans. Austr. Inst. Mg. Eng., Vol. 3, 1895, Adelaide, pp. 224-229.

The tin deposits of Tasmania are classed as alluvial, fissure lodes and stockworks, and impregnations. Examples of these types may be found at different mines, while at Mt. Bischoff the deposit is unusual, presenting almost all of these known types. The ore is practically confined to the granite regions and their immediate vicinity.

TASMANIA (Continued)

MOORE, T. On the occurrence of tin, zinc, silver, and traces of gold in the killas of St. Paul's Plains.

Pap. Proc. Roy. Soc. Van Diemen's Land, Vol. 2, pt. 3, 1854, Tasmania, p. 490.

MUFFORD, J. Tasmanian tin fields.

Mg. Journ. Railw. Comm. Gaz., Vol. 47, 1877, London, pp. 1383, 1411, 1439; Vol. 48, 1878, pp. 19, 48, 183.

A series of six articles, describing the country surrounding the tin-bearing districts, the deposits, methods of working and output. The output of Mount Bischoff from 1873-1877, given.

———. The tin mines of Tasmania.

Mg. Journ. Railw. Comm. Gaz., Vol. 48, 1878, London, p. 483.

Extract of paper read before Mining Institute of Cornwall, 1878, with discussion. Gives output of Tasmania for first half of 1878 and estimates whole output for the year. All derived from alluvial washings. Gives descriptions of the tin bearing districts. Believes Tasmanian mines have reached their highest production.

NEWMAN (——). Tasmanian tin.

Iron, Vol. 6, 1875, London, p. 711.

Extract of a report by author on the Mount Bischoff tin mines.

PETTERD, W. F. Minerals of Tasmania. Cassiterite.

Pap. Proc. Roy. Soc. Tasmania, 1893 [1894], Hobart, pp. 20-23.

Describes the different varieties of cassiterite found in Tasmania, where found and the principal tin-producing localities. Gives the production to close of 1892.

———. Catalogue of the minerals of Tasmania.

1896, Launceston.

Stannite occurs in considerable quantity in the Silver Queen mine at Zeehan, associated with galena, copper, and iron pyrites. The stannite is gold and silver bearing.

———. The minerals of Tasmania.

Pap. Proc. Roy. Soc., Tasmania for 1900-1901 (1902), Hobart, pp. 75-84.

A short article reviewing the mineralogy of the island in a concise manner.

———. Notes on Tasmanian minerals.

Rep. Secr. Min. for 1903, Tasmania, 1904, Hobart, pp. 74-75.

Abstract: Mg. Journ. Railw. Comm. Gaz., Vol. 76, 1904, London, p. 475.

Description of unusual tin specimens from several Tasmanian mines.

PHILLIPS, J. A., and LOUIS, H. *See* No. 1350.

PLUMMER, JOHN. Australia's premier tin mine.

Mg. Sci. Press, Vol. 100, 1910, San Francisco, p. 820.

Brief account of the dividends paid by Mount Bischoff tin mine, and the outlook for future productiveness.

RANFT, THEOD. Der Zinnbergbau am Bischoffsberge, Tasmania.

Berg. Hütt. Zeit., Vol. 48, 1889, Leipzig, pp. 351-353.

Brief digest: Neues Jahrb. Min., 1891, II [Ref.], Stuttgart, p. 295.

Short historical notices upon the growth of mining at Mt. Bischoff, the tin-ore occurrences of which have become better known through von Groddeck, also a sketch of the geological relations and technical operations.

TASMANIA (Continued)

1123. RATH, M. J. VON. Eine topographisch-montanistische Karte des Mount Bischoff auf Tasmanien.

Verh. Nat. Ver. preuss. Rheinl. Westph. (Sitzungsberichte), Vol. 35, 1878, Bonn, p. 7.

1124. REPORT of the Secretary for Mines, Tasmania.

Hobart.

Contains reports of the mining industry, progress and development work. Issued annually for the preceding fiscal year.

REYER, EDUARD. *See* Nos. 87 and 1354.

1125. RICKARD, EDGAR. The Briseis tin lead at Derby, Tasmania.

Eng. Mg. Journ., Vol. 75, 1903, New York, pp. 119-120. Sketch plan.

Describes placer cassiterite occurring in the gravel of a river 100 feet below the present streams. It is capped by basalt. Worked by a modification of the hydraulic system.

1126. RITCHIE, W. Tin in Tasmania.

Mg. Journ. Railw. Comm. Gaz., Vol. 43, 1873, London, p. 1109.

Extract from letter. Description of tin deposits of Mount Bischoff. Some pieces of tin ore were of such size that a man could not lift them. Both lode and alluvial tin ore of much richness occur. Great natural facilities for the working of mine.

ROLKER, CHAS. M. *See* No. 1357.

1127. ROWE, CAPT. JAMES. Tin mining in Tasmania.

Trans. Mg. Ass. Inst. Cornwall, Vol. 1, 1887, Camborne, pp. 153-163, map.

Also, Berg. Hütt. Zeit., Vol. 47, 1888, Leipzig, pp. 183-185.

First discovery of importance at Mount Bischoff in 1872, by Chas. Smith in a deposit "of a highly ferruginous nature, consisting of oxide of iron, decomposed porphyry and tin ore." Cut 1000 feet wide and 100 feet deep gave 3 per cent ore. Two other districts. Mt. Bischoff is in northwest portion, the "West Coast" region is just southwest of it, and the Northeast District is in the northeast part of the island. "West Coast" not paying. Deposits in northeast in both recent and old river beds partly covered by basalt. Gravel up to 170 feet deep in places, carrying about three-fourths per cent of ore worked by hydraulicking.

1128. SANDEMAN, J. J. The mineral resources of Tasmania.

Trans. North of England Inst. Mg. Mech. Eng., Vol. 49, 1901, Newcastle-upon-Tyne, pp. 32-37, illus.

Reprint: Trans. Inst. Mg. Eng., Vol. 18, 1899-1900, London, pp. 32-37.

The tin production of Tasmania holds, according to writer, the first place among the Australian colonies. Up to end of 1897, it produced 80,000 tons of tin, valued at £6,500,000; of this Mt. Bischoff contributed about £2,700,000. This mine is worked in three open faces or quarries: The Brown Face, the Slaughter Face and the White face. Descriptions of these quarries are given. The Blue Tier district is described as having intrusive dykes of stanniferous granite. The mines have suffered from poor management. There is every evidence that they should yield good paying ores, with modern appliances and good management.

1129. SHAW, A. Tin of Mount Bischoff, Blue Tier, and River Ringarooma.

Rep. Mines Dept., for 1883-1884, H. A. Paper, No. 70, 1884.

Not available to the authors.

1130. SHAW, B. Tin of Mount Bischoff, Mount Heemskirk, Blue Tier, Moorina, and Gladstone.

Rep. Mines Dept., 1884-1885, H. A. Paper, No. 58, 1885.

Not available to the authors.

TASMANIA (Continued)

OWDEN, C. To the Tasmanian tin mines.

Nat. Hist. Journ. School Rep., Vol. 17, 1893, York, pp. 6-8.
Digest from Ann. Brit. Geol., 1893, London, p. 347.
"A description of the works at Mount Bischoff."

TEPHENS, D. *See* No. 59.

TOKES, RALPH (S. G.). The Tasmanian tin industry.

Mg. World, Vol. 26, 1907, Chicago, pp. 718-719, 776-777, 806-807.
A series of illustrated articles giving a general review of the tin industry of Tasmania. Not much geology is given.

———. Mount Bischoff tin mine, Tasmania.

Mg. World, Vol. 27, 1907, Chicago, pp. 55-58. Illus.
General article giving account of the decreased output of Mt. Bischoff tin mine, owing to the working out of the Brown Face; also a description of the working of a new electric plant.

———. *See* No. 729.

ASMANIA. Government geologist. The mineral industry of Tasmania.

Published quarterly. Compiled by: Harcourt-Smith, J., from 1897 through March, 1899. Wallace, W. H., from June, 1899-. (From June, 1899 to December 31, 1901, not available to the authors.) Twelvetrees, W. H., from December, 1901.

HUREAU, G. Report on the Ben Lomond tin deposits. On the St. Paul's River tin deposits.

Tasm. Parl. Pap. No. 108, 1881, Hobart, pp. 4, plans.

———. The Blue Tier Mining District.

Geol. Surv. Rep., Tasmania, 1886, Hobart.
Not available to the authors.

REGAY, W. *See* No. 60.

WELVETREES, W. H. Report on some tin mines in the St. Paul's River valley near Avoca.

Rep. Secr. for Mines, for 1899-1900, Tasmania, 1900, Hobart, pp. XIV-XXVII, pls. 3.
Describes the Roy's Hill tin mine as being in Permo-carboniferous "wash and conglomerate" 20 feet thick and overlain by Jura-Trias sandstone. Beneath the deposit is a quartz-mica-tourmaline rock with some kaolin, from which the tin has been derived. Both are worked. Gives an exposition of the theory of pneumatolytic deposition, and advises further prospecting. The St. Paul's mines were at this time idle. They are in much silicified and tourmalinized granite. The cassiterite is well crystallized and often of amber or ruby color.

———. Report on the Arba extended tin sections at Branxholm.

Rep. Secr. for Mines for 1899-1900, Tasmania, 1900, Hobart, pp. XLI-XLIII.
Prospects are that the tin mines (placer) will be small. The gravel occurs in pockets in a granite which contains considerable tourmaline and many quartz veins. Some gold is found with the tin.

———. Preliminary report on the deep lead or infra-basaltic stanniferous gravels of the Ringarooma valley near Derby.

Rep. Secr. for Mines, for 1899-1900, Tasmania, 1900, Hobart, pp. CVII-CXXVII, sketch maps 2.
Tries to trace the old valley of the Ringarooma River under basalt by which it is covered. The river and tributary streams are known to have flowed through stanniferous granite so that it is supposed the gravels may pay for working. Where denuded both tin and gold have been obtained from the gravel.

TASMANIA (Continued)

1140. ———. Report on the mineral fields between Waratah and Corinna.

Rep. Secr. for Mines for 1899-1900, Tasmania, 1900, Hobart, pp. CXL-CCVII, plans 2.

Review: Austr. Mg. Stand., Vol. 18, 1900, Sydney and Melbourne, pp. 502-506.

Mt. Bischoff tin mine [pp. CL-CLVI], rises 500 feet above the Waratah plateau. The first discovery of tin ore was made by James Smith in 1871. The mine has been dividend-paying continuously since 1878; total dividends paid to date being £1,674,600; total tin ore to date, 57,358 tons; value £3,316,528.

The geology of the deposit is treated.

Webster's Workings [pp. CLVI-CLVII] and Ten-mile tin claim at White River Bridge [pp. CLVII-CLIX] are alluvial tin claims.

1141. ———. Report on the tin mines of Blue Tier, county of Dorset.

Geol. Surv., Tasmania, 1901, Hobart, pp. 33, figs. 9.

Also in Rep. Secr. Mines, Tasmania, 1901-1902, Hobart, pp. 90-123.

Supposing only that the tinstone continues a very little below already proved depths, there is sufficient tin bearing rock to keep several mines going for a good many years. If it descends indefinitely, there is enough stone for generations. If the dyke theory is correct, there is no reason why it should not persist to great depth. If the floor theory is the right one, it will still descend to any required depth. The development of the mines appears to be governed by the water power available. With adequate water supply, the district would undoubtedly be a busy tin-producing center. It is a productive district as it is, but its production is intermittent, being dependent upon rainfall. Author holds high hopes of a future for the Tier. The mines of the district are described individually.

1142. ———. The Bell Mount Mining Field.

Journ. Print. Pap. Parl., Tasmania, Vol. 45, 1901, Hobart, pp. 57-60.

Not available to the authors.

1143. ———. Report on the tin-bearing capabilities of the Gladstone district.

Journ. Print. Pap. Parl., Tasmania, Vol. 45, 1901, Hobart, pp. 72-83, geol. map 1.

Also in Rep. Secr. for Mines, Tasmania, 1901, Hobart, pp. 232-267, plan.

Digest: Geol. Centr., Vol. 2, 1902, Leipzig, p. 581.

The tin ore occurs principally in gravels spread far and wide over the surface of the country. The changes in level of the land since Tertiary times and their effect on the tin deposits, as also that of lava streams, is described. Topaz, sometimes very fine, and sapphires occur in the drift.—Geo. W. Card.

1144. ———. Report on the coal field of Llandaff, the Denison and Douglas rivers, on the deposits of tin ore on Schouten Main, and on out-crops of quartz near Buckland.

Rep. Secr. for Mines, for 1901-1902, Tasmania, 1902, Hobart, pp. 52-62, sketch maps 2.

"Schouten Main is the name used for that part of the mainland which is at the head of Freycinet's Peninsula, and consists of granite, with the exception of some Silurian metamorphic sandstone on the crest and east slope of the hill overlooking Bluestone Bay."

It is estimated that 150 tons of alluvial tin ore has been mined—it is possible that large lodes exist in the granite, that have eluded discovery, but the author would give different sources for it:

1. Small quartz veins enclosing coarse tin.
2. Greisenised bands of granite containing small quantities of ore.

1145. ———. Report on mineral fields between Waratah and Long Plains.

Geol. surv., Tasmania, 1903, Hobart, pp. 38.

Badger tin mines, pp. 35-37.

Situated 5 miles from Waratah. Tin occurs in kaolinized and silicified porphyritic granite. Samples assayed 7.77 to 9.2 per cent metallic tin. Some alluvial tin. Little work done.

TASMANIA (Continued)

———. Report on the Renison Bell tin field.

Geol. Surv., Tasmania, 1906, Hobart, pp. 12.

Renison Bell tin mine, the chief mine of the Dundas tin-bearing belt, is situated at the northern end of the area. At present worked by optionees, producing ore by sluicing; are driving underground to intersect a large pyrrhotite lode a hundred feet below its exposure in a railway cutting. District is undeveloped. Present price of tin is acting as a stimulus that will lead to working lodes.

———. Geological report on Cox's Bight tin field.

Geol. Surv., Tasmania, 1906, Hobart, pp. 18, geologic map 1.

A little known field on the south coast of Tasmania, 36 miles by water from Recherche, and three or four days walk overland. A biotite granite boss of Devonian age, 1¼ miles in diameter, intruded through quartzite and schist is intersected by veins carrying cassiterite and accessory molybdenite. Tin found here in early '90's, and about 120 tons taken out to 1906. Gives individual descriptions of several claims. Yield, 1 pound to 7½ pounds per cubic yard, generally nearer the smaller figure. Gravel 6 feet and more thick. Field restricted.

———. Report on the Bell Mount and Middlesex district (Tasmania).

Geol. Surv., Tasmania, 1907, Hobart, pp. 1-30.

At Shepherd & Murphy mine, on Bismuth Creek, a tin-tungsten-bismuth vein occurs in a wollastonite-epidote rock, evidently altered limestone. Vesuvianite, diopside and garnet also occur. Granite or quartz-porphyry supposed to exist close at hand. Topaz occurs in the vein with quartz. The vein cuts Middle Silurian rocks. Also mentions quartz bismuth-tungsten veins at All Nations mine; tin-bearing stockworks in granite and quartz-porphyry, at All Nations and Dolcoath mines; alluvial deposits of gold, tin and tungsten and veins carrying pyrite, galena, molybdenite, "cupriferous quartz," gold and silver occur in the same district. Spodumene is found in one of the veins.

———. The mineral industry of Tasmania. *See* No. 1134.

TWELVETREES, W. H., and PETTERD, W. F. On the topaz quartz porphyry or stanniferous elvan dykes of Mount Bischoff.

Pap. Proc. Roy. Soc., Tasmania, 1897 (1898), Hobart, pp. 119-128, pl. 1.

The dikes of Mt. Bischoff are granitic and both feldspar and quartz have been more or less replaced by topaz and to a lesser degree, cassiterite, so that the latter mineral is also secondary.

TWELVETREES, W. H., and WARD, L. KEITH. Geological examination of the Zeehan field.

Geol. Surv., Tasmania, Bull. No. 7, 1909, Hobart, pp. 25. (Preliminary statement.)
Extract: Mg. Journ. Railw. Comm. Gaz., Vol. 87, 1909, London, pp. 532-534.

Treated under heads: Introduction; nature of the examination; its scope and method; forecast of the forthcoming report; preliminary statement of the results of the geological examination.

ULRICH, G. H. F. A report on Mount Bischoff tin mines, Tasmania, with topographical sketch map.

1874, Launceston, pp. 5.
Not available to the authors.

———. Ueber die Zinnmine am Mt. Bischoff in Tasmanien.

Neues Jahrb. Min., 1877, Stuttgart, pp. 494-497.

WADDINGTON, H. Tin; its future.

Mg. Journ. Railw. Comm. Gaz., Vol. 40, 1879, London, p. 1310.
Extracts from a report by H. W. F. Kayser on the Bischoff tin mines.

TASMANIA (Continued)

1152a. WALLACE, W. H. The mineral industry of Tasmania. *See* No. 1134.

1153. WALLER, G. A. Report on the mining districts of the Scamander River and St. Helens.

Rep. Secr. for Mines, 1900-1901, Tasmania, 1901, Hobart, pp. 268-301.

Alluvial deposits of tin at the Scamander River and at St. Helens.

A description of the following mines is given: The Scamander Tin and Gold Co.; the mines at St. Helens; Royal Ruby Tin Mining Co.; Fern Tree Creek; Saxelby Creek; Thureau's Deep Lead Tin Mining Co.; Fenton's Mine; the Upper Ruby; the Rose Tin Co., Ltd.

1154. ———. Tin mining at St. Helens, Tasmania.

Austr. Mg. Stand., Vol. 20, October 17, 24, 31, 1901, Sydney and Melbourne. Serial, 3 parts, 4000 words.

"Describes the deposits and various workings."

Not available to the authors.

1155. ———. Report on the tin mining district of Ben Lomond.

Journ. Print. Pap. Parl. Tasmania, Vol. 45, 1901, Hobart, pp. 95-107, geol. sketch map 1, figs. 3.

Also in Rep. Secr. for Mines, Tasmania, 1900-1901, Hobart, pp. 302-342.

Digest: Geol. Centr., Vol. 2, 1902, Leipzig, pp. 580-581.

Tin occurs in silicified and pegmatitic portions of Devonian granite, which breaks through Silurian slates, sandstones, etc. Considers tin to be of pneumatolitic origin. Accompanied by tourmaline, beryl, fluorspar, chlorite, argentiferous-galena, zinc blende, chalcopyrite, arsenopyrite and pyrite, wolframite, and probably gold. In one occurrence, considers tin in a fine grained granitic rock to be original. Some veins in neighborhood carry considerable quantities of wolframite. Describes different mines and gives rainfall.

1156. ———. Tin ore deposits of Mount Heemskirk.

Geol. Surv., Tasmania, 1902, Hobart, pp. 46, pls. 4.

Review: Austr. Mg. Stand., Vol. 28, 1902, Sydney and Melbourne, pp. 441, 5[illegible].

Five miles from coast between Trial and Granville harbors. Geology of the district described. Four kinds of veins carry SnO_2 viz.: Quartz-tourmaline veins, pinite-quartz (decomposed feldspar) veins, greisen veins, and pyritic veins. Tin occurs in nodules of quartz and tourmaline, sometimes hollow, generally in aplite segregations, but sometimes in the granite. Green tourmaline more apt to occur with tin than black tourmaline. Much of tin in residual gravel in gray colored nuggets with granular center covered by thin concentric layers, frequently layers are radiating. Residual gravel 1 foot to 3 feet deep, gave 7.7 per cent cassiterite. Extent unknown. Some rich veins carry up to 39 per cent tin. Tin ore spreads out from veins into sandstone, parallel to bedding.

Treats nineteen tin localities of district. Thinks region has good future.

1157. ———. Report on the tin-ore deposits of North Dundas.

Rep. Secr. for Mines, 1901-1902, Tasmania, 1902, Hobart, pp. 139-158, pls. 1, 2, plan and section, Renison Bell mine.

Most of the deposits of tin ore are located in the center of the northeast Dundas District. Most of the ore consists of dense iron-pyrites and pyrrhotite, with small grains of tin oxide embedded in it. Following mines are described:

1. Penzance Tin Mining Co. 2. Mount Lyell Copper Estate Co. 3. Cornwall Tin Mining Co. 4. Renison Bell Prospecting and Mining Co.

1158. ———. Report on the prospects of the Stanley River tin field.

Geol. Surv., Tasmania, January, 1904, Hobart, pp. 1-19, map 1.

On Stanley River, a tributary of the Pieman, West Tasmania. Field five miles long. Rocks, granite, porphyry and aplites, in southern part "older Silurian metamorphic sandstones and claystones." Tin of pneumatolitic origin. Feldspar

TASMANIA (Continued)

replaced by tin, tourmaline and quartz. Tin lodes consist of a zone of replaced granite (quartz tourmaline), with usually a central seam or fissure filled with tourmaline and tin, which may vary from a few inches to many feet in width. Pyrites and monazite occur in some veins. The small amount of work done has not only shown the presence of rich alluvial tin, but has afforded evidence of the presence of rich lode tin.

WARD, L. KEITH. The tin field of North Dundas.

Geol. Surv., Tasmania, Bull. No. 6, 1909, Hobart, pp. 166. Locality map, pls. 5.

Extract: Mg. Journ. Railw. Comm. Gaz., Vol. 86, 1909, London, pp. 232-233.

Treated under heads: Introduction; previous literature on the field; physiography; general geology; economic geology; history of mining on the field; the mining properties.

WELLINGTON, WM. Notice on Mount Bischoff, Tasmania.

Trans. Roy. Geol. Soc. Cornwall, Vol. 9, 1875, Penzance, pp. 161-162.

Author thinks tin of Mt. Bischoff is the result of volcanic eruptions, Mt. Bischoff being an extinct volcano.

First deposit, of about 6 feet, is composed of small detached pieces of porphyry, granite and tin disseminated through it.

Second eruption is more granite, in shape of large boulders and not so much tin.

Last eruption appears to have been more violent sending up large masses of granite and the greatest quantity of tin.

WICKHAM, F. D. The tin products of Mount Bischoff, Tasmania.

Mg. Journ. Railw. Comm. Gaz., Vol. 44, 1874, London, p. 396.

———. The tin mines of Tasmania.

Mg. Journ. Railw. Comm. Gaz., Vol. 48, 1878, London, p. 483.

WILLIAMS, GERARD W. Notes on the Zeehan mining field, Tasmania.

Eng. Mg. Journ., Vol. 89, 1910, New York, pp. 713-715, diagrams 2.

WILSON, A. P. Minerals and mining in Tasmania.

Trans. Fed. Inst. Mg. Eng., Vol. 7, 1893-1894, Newcastle-upon-Tyne and London, 1894, pp. 277-278.

Also, Trans. North of England Inst. Mg. Mech. Eng., Vol. 43, 1894, Newcastle-upon-Tyne, p. 335.

Short account of Mt. Bischoff tin mining. Other districts mentioned as important are: Ringarooma, Branxholme, George's Bay and Blue Tier.

Author thinks Tasmania is destined to occupy a more prominent place as a tin producing district. Further examination will doubtless bring to light massive lodes of tinstone which have been the source of the great alluvial deposits of the island.

WINTLE, S. H. Stanniferous deposits of Tasmania.

Trans. Proc. Roy. Soc. New South Wales, for 1875, Vol. 9, 1876, Sydney, pp. 87-94, fig. 1.

Extract: Mg. Journ. Railw. Comm. Gaz., Vol. 45, 1875, London, pp. 1095-1096.

Mount Bischoff tin deposits in eurite porphyry thrust through Paleozoic rocks, "clay-slate, altered sandstone, limestone, conglomerate and quartzose rock."

Limestones carry argentiferous galena, tin- and iron-pyrites and bismuth. All covered by basalt. Mount Bischoff 3500 feet altitude. Tin ore occurs as veins and lodes in porphyry.

Description of tin ore occurrence at Mt. Ramsay.

———. Notes on the mineral resources of Tasmania.

Eng. Mg. Journ., Vol. 28, July 19, 1897, New York, pp. 38-39.

An outline of the geological and commercial features of the island, including the tin resources.

TEXAS (Continued)

PAVLOV, ALEXANDER W. *See* No. 1216.

70. RICHARDSON, G. B. Tin in the Franklin Mountains, Texas.

U. S. Geol. Surv. Bull. 285, 1906, Washington, D. C., pp. 146-149, fig. 1.

Description of the El Paso tin deposits, first described by Weed in U. S. Geol. Surv. Bull. 178, 1901. Gives a general description of the topography and geology of the Franklin Mountains, and a partial analysis of the tin bearing granite. The tin deposits are close to faults. Found little new development. States that water can be obtained in the mesa east of the mountains.

71. STREERUWITZ, W. H. VON. Report on the geological and mineral resources of Trans-Pecos, Texas.

2d Ann. Rep. Geol. Surv. Texas, 1890 (1891), Austin.

Mentions finding traces of tin in West Texas ores.

72. WEED, WALTER H. The El Paso tin deposits (Texas).

U. S. Geol. Surv. Bull. 178, 1901, Washington, D. C., pp. 1-15, pl. 1, figs. 1-4.

Digest: Neues Jahrb. Min., 1902, II (Ref.), Stuttgart, p. 342.

Reprinted, U. S. Geol. Surv. Bull. 213, 1903, pp. 99-102.

Describes briefly the geological structure and formation of the Franklin Mountains. Thinks the veins are similar to those of Cornwall, and that the ores are formed largely by replacement. Notes the absence of topaz and presence of wolframite.

TRANSVAAL AND RHODESIA

73. ANONYMOUS. Discovery of tin in the Transvaal.

California Journ. Tech., Vol. 2, No. 3, 1903, Berkeley, p. 53.

Quotes from the "British South African Export Gazette," of September 4, 1903, that three tin-bearing lodes have been discovered in the Transvaal.

74. ———. Gold and tin in northern Rhodesia.

Austr. Mg. Stand., Vol. 32, 1904, Sydney and Melbourne, p. 373.

Taken from South African Mines, reports a deposit of stream tin on west bank of Lualaba.

75. ———. Tin discoveries in the Bushveld.

Journ. Soc. Arts, Vol. 52, 1904, London, pp. 736-737.

A summary of particulars respecting the discovery of tin in the Bushveld, near Pretoria, taken from the "African Review."

76. ———. Tin in the Transvaal.

Mg. Sci. Press, Vol. 89, 1904, San Francisco, p. 295, 250 words. (Probably from Hall, A. L., No. 1181.)

Digest: Mg. Mag., Vol. 10, New York, p. 442.

"Notes on the occurrence of this metal in several different places in the Transvaal."

77. ———. Tin in the Transvaal.

Mg. World, Vol. 24, 1906, Chicago, p. 774.

States that the first output of tin in the Transvaal has recently been declared. Tin lodes in various forms have been traced over a considerable area. Other tin areas in the neighborhood are being discovered from time to time.

78. ———. Failure of tin mine at Vlaklaagte, South Africa.

Eng. Mg. Journ., Vol. 82, 1906, New York, p. 180.

It was expected that this mine would prove one of the world's greatest deposits. Unless things improve considerably, the tin mine at Vlaklaagte cannot run much longer. Up to date the total amount of material won is roughly 25½ long tons cassiterite equal to 17.85 tons or 1.75 per cent metallic tin, from 1020 tons treated.

TRANSVAAL AND RHODESIA (Continued)

1178a. ———. Potgietersrust tin fields.

South African Mg. Journ., May 23, 1908, Johannesburg, pp. 1½.
Not available to the authors.

1178b. ———. The Groenfontein tin plant.

South African Mg. Journ., July 4, 1908, Johannesburg, p. ¾.
"Describes methods for the recovery of tin in the Potgietersrust field, and also a new plant which is to be built."
Not available to the authors.

1178c. ———. Base metals in the Transvaal.

Eng. Mg. Journ., Vol. 88, 1909, New York, p. 250.
Briefly describes tin producing districts of the Transvaal.

1178d. ———. Tin deposits of the Transvaal.

Eng. Mg. Journ., Vol. 88, 1909, New York, p. 778.
Describes the manner of occurrence in the various fields.

1178e. ———. Zaaiplaats tin mines.

South African Mg. Journ., Vol. 7, pt. 1 (Feb. 13), 1909, Johannesburg. Illus.
"Describes the plant and workings, going into the geology of the deposits."
Not available to the authors.

1178f. ———. Notes on the tin fields.

South African Mg. Journ., Vol. 7, pt. 1, 1909, Johannesburg, p. 109, illus.
Describes some occurrences and operation on Groenvlei.

1178g. ———. Transvaal tin: establishment of an industry.

South African Mg. Journ., Vol. 7, pt. 1, 1909, Johannesburg, p. 145.
Gives encouraging reports from the Waterberg, also an account of activity at Rooiberg and Weynek.

1178h. ———. Waterberg tin mines.

South African Mg. Journ., Vol. 7, pt. 1, 1909, Johannesburg, p. 407.
Very encouraging outlook for tin-mining becoming a great industry in this colony.
Describes activity at Zaaiplaats property—geological features, extension of plant, scarcity of labor, etc.

1178i. ———. The government tin report.

South African Mg. Journ., Vol. 7, pt. 1, 1909, Johannesburg, No. 358, pp. 719-721, pl. 1.
Deals with the tin industry of the Waterberg field, which is treated under heads: General geological structure; the tin rocks; the tin limits; investigation in depth; the shale-felsite deposits; the Rooiberg quartzites.

1178j. ———. The Transvaal tin industry to-day.

South African Mg. Journ., Vol. 7, pt. 2, 1909, Johannesburg, pp. 253-254.
Treated under heads: Some monthly reports; the Groenfontein profits; alleged secondary enrichment at Rooiberg; prospects at Doornhoek.

1178k. ———. Tin in Rhodesia: the beginning of an industry.

South African Mg. Journ., Vol. 7, pt. 2, No. 350, 1909, Johannesburg, p. 279, 400 words.
Probably reference to same occurrence in Mines & Min., Vol. 30, 1909, p. 11—quoted from U. S. Consular report.
Note on the discovery of tin at Rusapi on the Salisbury-Beira line.

TRANSVAAL AND RHODESIA (Continued)

. DAVEY, T. G. Trans-Zambesian mining.

Mg. Journ. Railw. Comm. Gaz., Vol. 73, 1903, London, p. 158.

"In many instances the granite and porphyries, which I traversed, show promising indications of the presence of tin." Whole reference.

. GRIFFITH, H. D. Largest tin producing fields in the world.

South African Mines, December 3, 1904, Johannesburg, 2000 words.

"Abstract of a report on the Bushveld tin properties; character of deposits, results of development, and estimate of costs."

. HALL, A. L. The geological survey of the northeastern portions of the Pretoria district, including the tin fields.

Transvaal Mines Department, Report Geological Survey for 1904 (1905), Pretoria, pp. 37-44, pls. 15, 22, map 1.

The larger part of the article is devoted to the general geology of the district. A coarse red granite at Bushveld (Enkeldoorn), 42 miles northeast of Pretoria, is apparently the youngest of the rocks except diabase, and is intrusive in a felsite. Finer grained portions, probably a later phase, carry the cassiterite in microscopic grains. One lode is about 12 feet wide at the surface, and is said to carry 1.5 per cent tin. The Vlaklaagte deposits are 12 miles further northeast. Here cassiterite is rather evenly distributed through a gray granite cutting the coarse red granite. Cassiterite crystals are ⅛ inch and less long. Topaz and mica also occur, and the author supposes the deposit to be due to pneumatolytic action.

. ———. Geological notes on the Bushveld tin fields and surrounding area.

Trans. Geol. Soc. South Africa, Vol. 8, 1905, Johannesburg, pp. 47-55, pls. 9, 10, [geol. map and section of vein].

Practically the same article as No. 1181.

. JOHNSON, J. B. The tin, molybdenum and lead occurrences near Potgietersrust.

Trans. Geol. Soc. South Africa, Vol. 10, 1908, Johannesburg, pp. 115-119.

The tin deposits occur between the Magalakwin and Sterk rivers. A quartz vein carries coarsely crystalline cassiterite, which is sparsely distributed in fine crystals through the granite for a width of 40 yards. Fluorite is an accompaniment in both vein and granite. Peculiar round pipes in the granite also carry cassiterite. Other minerals with the cassiterite are molybdenite, pyrite, chalcopyrite, arsenopyrite, galena, copper, tourmaline and a greenish mica. Attributes tin, molybdenum and lead deposits to pneumatolytic metasomatism.

a. KYNASTON, H. Cassiterite deposits of the Waterberg.

South African Mg. Journ., Nov. 21, Dec. 12, 1908, Johannesburg. See 1183b.

b. ———. Report on a preliminary examination of the cassiterite deposits of Zaaiplaats, and some of the neighboring farms of the Waterberg district.

Transvaal Mines Dep., Rep. Geol. Surv. for 1907 (1908), Pretoria, pp. 91-102, figs. 5-7.

Reprint: South African Mg. Journ., Nov. 21, and Dec. 12, 1908, Johannesburg.

Deposits at Zaaiplaats, Groenfontein and Roodepoort are described.

The cassiterite occurs in the red (Bushveld) granite in pipes and chutes. The former are cylindrical bodies of altered granite impregnated with ore and sometimes surrounded with a selvage of tourmaline, fluorspar, copper and arsenic pyrites, specular iron ore, blende, galena, stibnite, wolframite, and molybdenite.

TRANSVAAL AND RHODESIA (Continued)

1183c. LAWN, —. South African tin mines.

South African Mg. Journ., Vol. 7, pt. 2, 1910, Johannesburg, p. 660.

Extracts from report of Consulting Engineer Lawn of the Doornhoek mine of South African Tin Mines Company, Ltd., Transvaal. He reports very promising outlook.

1184. MERENSKY, H. Neue Zinnerzvorkommen in Transvaal.

Zeitschr. prakt. Geol., Vol. 12, 1904, Berlin, pp. 409-411, 1000 words.

Digests: Neues Jahrb. Min., 1906, II (Ref.), Stuttgart, p. 228.

Geol. Centr., Vol. 7, 1905-1906, Leipzig, pp. 328-329.

Mg. Mag., Vol. 11, 1905, New York, p. 369.

South African Mines, Vol. 2, 1904, Johannesburg, p. 512.

The new occurrence is in Enkeldoorn district, 40 miles northeast of Pretoria. The ore could be readily concentrated and smelted where found, water and coal being close at hand. Prospecting is now under way.

1184a. ———. The rocks belonging to the area of the Bushveld granite complex, in which tin may be expected, with descriptions of the deposits actually found. (Read March 16, 1908.)

Trans. Geol. Soc. South Africa, Vol. 11, 1908, Johannesburg, pp. 25-42.

Discusses the general theory of tin deposition, the rocks surrounding the South African deposits, and their relative ages. He then takes up the tin deposits and discusses them and their accessory minerals and also other veins which seem to have close relations to the tin veins. Treats the Rooiberg, Warmbaths, Nylstroom and Potgietersrust districts. Believes the tin ore was deposited largely from thermal solutions.

1185. ———. Potgietersrust tin fields.

South African Mines, May 23, 1908, Johannesburg.

"Treats of output to date, geology of district, failure of government scheme and success of private producer."

Not available to the authors.

1185a. MILLS-DAVIES, J. E. The Transvaal tin industry.

South African Mg. Journ., Vol. 7, pt. 1, 1909, Johannesburg, pp. 403-405, 493-494, 547-548, 575-576, 605-606. Illus.

A series of five articles.

I. Treats of tin mining at Nylstroom.

II. Treats of Potgietersrust district.

III. Treats of Warmbaths district, describing especially the Rooiberg mine, and ancient Rooiberg workings.

IV. Continues description of Rooiberg mines, extent of lodes, ore chutes and value.

V. Describes Rooiberg dressing plant. Yield to date.

New discoveries in Rooiberg district are described in Vol. 7, pt. 2, 1910, p. 495.

1186. PRAAGH, L. V. The Transvaal and its mines.

London and Johannesburg (1907), pp. 631-633.

States that cassiterite occurs along the Transvaal-Swaziland border on the watersheds of Steynsdorp Creek and Black Umbelosi and Little Usutu rivers in pegmatite accompanying gneissoid and schistose rocks. In September, 1906, the mines of this area were idle, owing to paucity of ore. Gives history of discovery of Bushveld (Vlaklaagte) deposits. Tin ore on the Enkeldoorns farm in this area is in thin quartz veins cutting a coarse red granite and in the rock between the veins. Describes the unsuccessful working of these mines. Refers to several other prospects in the Great Red Granite Laccolite.

1186a. RECKNAGEL, R. On some mineral deposits in the Rooiberg district.

Trans. Geol. Soc. South Africa, 1909, Johannesburg, pp. 83-106, pls. 6-16.

Read July 20, 1908.

Abstract: Mg. Journ. Railw. Comm. Gaz., Vol. 84, 1908, London, p. 778.

TRANSVAAL AND RHODESIA (Continued)

Describes the geology of the country in the neighborhood of Rooiberg, 40 miles west of Warmbaths. Tin occurs in granite, in irregular pockets, as veins in sediments and replacement deposits in quartzite. In one group of replacement deposits cassiterite occurs with cobaltite, scheelite, cupro-scheelite, wolframite, and tourmaline. Nickel deposits are possibly connected with the tin deposits. The tin deposits were worked long ago as shown by old pits, slag-dumps, etc., but by whom is unknown.

SIMMERSBACH, W. Die neuen Entdeckungen von Zinnerzlagerstätten in Transvaal.

Zeitschr. Berg. Hütt. Sal. preuss. Sta., Vol. 53, 1905, Berlin, pp. 245-248.
Digest: Geol. Centr., Vol. 7, 1905-1906, Leipzig, p. 521.
"Im roten Granit 35-50 engl. Meilen nordöstlich von Prätoria setzen die Zinnerzgänge in einem 11m mächtigen bisweilen sich teilenden Hauptgange und 8 kleineren parallel verlaufenden Nebengängen auf."—K. Keilhack.

STEWART, D. S. S. The mineral wealth of Zoutpansberg: the Murchison Range gold-belt.

Trans. Inst. Mg. Eng., Vol. 17, 1898-1899, London and Newcastle-upon-Tyne, p. 424.
"Tin occurs as stream tin at the Great Letaba River and also in veins in the granite which contains large orthoclase crystals." Whole reference.

SWINBURNE, U. P. Government tin prospecting in Transvaal.

Mg. Journ. Railw. Comm. Gaz., Vol. 83, 1908, London, p. 7.
Extract from Government Gazette, November 29, 1907. Deposits located at Zaaiplaats, 22 miles northwest of Potgietersrust. Ore occurs in: (a) more or less isolated ore chutes or chimneys in the red granite, (b) pegmatites and coarse granite containing large tin crystals, (c) alluvial or shed tin, probably derived from the rocks referred to in (b).

———. The economic aspect of Waterberg tin field.

South African Mg. Journ., Vol. 7, pt. 1, Nos. 337, 338, 1909, Johannesburg, pp. 695-699, 719-721.
Describes various mines and reviews their prospects.

UNITED STATES

ANONYMOUS. Tin in America.

Mg. Journ. Railw. Comm. Gaz., Vol. 58, 1888, London, p. 384.
An enthusiastic outlook for American tin.

———. Our tin mines.

Eng. Mg. Journ., Vol. 54, 1892, New York, p. 98.
Editorial. Treats of tin mining in the United States.

———. Tin mining in United States.

Mg. Sci. Press, Vol. 82, 1901, San Francisco, p. 143, illus. 2.
Tin deposits of Southern California and South Dakota are recorded as only deposits in United States which might be made paying. Both are described, with brief history of South Dakota tin boom, and unsatisfactory results.

———. Tin in United States.

Mg. Sci. Press, Vol. 87, 1903, San Francisco, p. 117.
Brief outline of tin developments in United States. Deposits of York, Alaska, are most promising, because unproven. The stone occurs there in abundance, though the veins have not been explored.

UNITED STATES (Continued)

1194. ———. Tin in United States.

Mg. Sci. Press, Vol. 87, 1903, San Francisco, p. 282.
Editorial. Giving brief outline of the tin mining industry of United States.

1195. ———. The production of tin in 1903.

Mg. Rep., Vol. 50, 1904, Denver, p. 632, 700 words.
Editorial. Short review of tin deposits in United States and their outlook.

1196. ———. Tin in United States.

Mg. Sci. Press, Vol. 89, 1904, San Francisco, p. 385.
Rather general and brief review of tin deposits of the Carolinas; Black Hills of South Dakota; Southern California and Alaska.

1197. ———. Development of American tin deposits.

Iron Age, December 8, 1904, New York, 1800 words.
Review of the tin industry taken from the United States Geological Survey reports.

1198. ———. The search for tin.

Mg. Rep., Vol. 51, 1905, Denver, pp. 624-625, 1500 words.
"Gives a summary of places in the United States where tin ore is known to have been found, with a brief description of the mode of occurrence and means for determining the mineral."

1199. ———. Tin mining in United States.

Eng. Mg. Journ., Vol. 81, 1906, New York, pp. 474-475.
Editorial on the prospect of profitably mining low grade tin ore in the United States.

BECK, RICHARD. *See* No. 1299.

1200. BENEDICT, WM. DE L.

Min. Ind. for 1892, Vol. 1, 1893, New York, pp. 452-457.
Tin deposits of California, South Dakota, North Carolina, Virginia and Alabama treated.

1201. BLAKE, WM. P. Occurrence of tin ore (wood-tin) in California, Idaho and Montana.

Mg. Sci. Press, Vol. 45, 1882, San Francisco, p. 89.
Stream tin has been found in the alluvions of the middle fork of the Feather River about 3 miles above Big Bar, in Plumas County, California.
"The many points at which the ore has been found in Montana and Idaho indicate that this important ore has a wide and general distribution in the granitic region of the northwest, particularly in the Rocky Mountains at the headwaters of the Missouri and in the western drainage, including the streams flowing from the Bitter Root range, especially in the Snake and the Salmon and their affluents."

1202. ———. Ores of tin.

Min. Res., U. S. Geol. Surv., 1883-1884, Washington, D. C., pp. 592-640.
Contains chapters on: Ores of tin; origin of tin ore; tin ore in the New England States; tin ore localities in the Middle and Southern States; tin ore in the Black Hills of Dakota, in Wyoming, Idaho and Montana; tin ore in California; foreign sources of tin; physical properties of tin; alloys of tin; the tin plate industry and prices, exports, etc.

D'ACHIARDI, ANTONIO. *See* No. 1313.

UNITED STATES (Continued)

1203. DAY, DAVID T. Tin.

Min. Res. U. S. for 1891, U. S. Geol. Surv., 1893, Washington, D. C., pp. 164-166. Treats of the development of the tin mines of United States during 1891.

1203a. ———. Tin. Mineral Industries of the United States.

Eleventh Census. Census Office, 1892, Washington, D. C., pp. 249-265.

Treats of the occurrence of tin in Massachusetts, New Hampshire, Maine, Virginia, North Carolina, Georgia, Alabama, Texas, California and South Dakota. The conditions of occurrence in the Black Hills is treated at some length, development work done, and a list of claims given. Also treats of the foreign production of tin.

1204. DOUGLAS, JAS. Summary of American improvements and inventions in ore crushing and concentration, and in the metallurgy of copper, lead, gold, silver, nickle, aluminum, zinc, mercury, antimony and tin.

Trans. Amer. Inst. Mg. Eng., Vol. 22, 1894, New York, p. 343.

"Tin is widely diffused from Maine to Alabama in Appalachian Range, exploited from Dakota to California, but the mining of it so far has nowhere been sufficiently remunerative to create a smelting industry."

1205. EMMENS, STEPHEN H. American tin mines.

Eng. News Amer. Railw. Journ., Vol. 28, 1892, New York, pp. 484-486.

Abstract of reports of J. Thomas and Lord Thurlow on Harney tin mines. Also brief review and prospects of the tin deposits in North Carolina, California and Virginia.

1206. EMMONS, S. F. Geological distribution of useful metals in United States.

Trans. Amer. Inst. Mg. Eng., Vol. 22, 1893, New York, pp. 71-72.

Describes the geological occurrence in different parts of the United States of iron, manganese, nickel, tin, copper, lead, zinc, quicksilver, gold and silver, and gives a summary of conclusions concerning the genesis of their minerals.

FAWNS, SYDNEY. *See* No. 1320.

FUCHS, E., and LAUNAY, L. DE. *See* No. 1323.

1207. GARRISON, F. LYNWOOD. Tin in the United States.

Eng. Mg. Journ., Vol. 78, 1904, New York, pp. 830-832.

Reprint: Min. Ind. for 1904, Vol. 13, 1905, New York and London, pp. 400-405.

Brief review of history of discoveries of tin in this country. Summary of occurrence in Black Hills, at Temescal, York River, Virginia, North and South Carolina. Compares United States deposits with those in different parts of the world.

Gives average yield from some principal producers elsewhere. Short sketches of occurrence in Bolivia and Malay Archipelago.

1208. HEADDEN, W. P. Mineralogical notes, No. III.

Proc. Colorado Sci. Soc., Vol. 8, 1906, Denver, pp. 167-173.

Pp. 167-168 give an analysis of cassiterite (credited to "Mecklenberg, N. C.," but probably from further west or south in the tin belt), which contains SnO_2 95.18, FeO, 1.11 and Ta_2O_5 3.82. Sp. gr. 6.7671. Pp. 169-170: Cassiterite which he thinks resulted from the decomposition of stannite, from the Etta mine, South Dakota, gave SnO_2 94.36, Ta_2O_5 2.42, Fe_2O_3 1.80, SiO_2 1.00.

Analyses of cassiterite from Herbert's Placer and the Sammelias claim No. 3, Pennington County, South Dakota, showed only iron and SiO_2 as impurities.

1209. HESS, FRANK L. Tin.

Min. Res. U. S. for 1905, U. S. Geol. Surv., 1906, Washington, D. C., pp. 445-451.

UNITED STATES (Continued)

1210. ———. Tin.

Min. Res. U. S. for 1906, U. S. Geol. Surv., 1907, Washington, D. C., pp. 543-549.

The production of tin in the United States during the year is reviewed and estimates made of the world's production.

1211. ———. Tin.

Min. Res. U. S. for 1907, Geol. Surv. 1908, Washington, D. C., pt. 1, pp. 725-729.

Reviews briefly the production of tin in the United States, imports, market conditions and prices. Gives an estimate of the world's production and the amount recovered in the United States from secondary sources.

Similar articles were published in the volumes for 1908 and 1909.

1212. KEMP, J. F. Zinn in den Vereinigten Staaten von Nord-Amerika.

Zeitschr. prakt. Geol., 1896, Berlin, p. 233.

Brief paragraph stating different localities where tin has been found in the United States.

1213. KEMP, JAS. F. The ore deposits of the United States and Canada.

3d Edition, New York, 1900, pp. 441-444, fig. 1. Bibliography.

Edition of 1898: pp. 273-274.

Edition of 1895: pp. 324-325.

General description of tin.

Short account of deposits in Black Hills, Montana, Idaho, California, Virginia, North Carolina, Alabama, Maine, New Hampshire and Texas. The tin of Mexico is also briefly treated.

1214. LEONHARD, GUSTAV. Topographische Mineralogie der Vereinigten Staaten von Nord-Amerika.

Neues Jahrb. Min., 1849, Stuttgart, p. 836.

Tin is mentioned as occurring at Goshen, Massachusetts; Jackson, New Hampshire; and in Virginia.

LOCK, C. G. WARNFORD. *See* No. 1338.

LOUIS, HENRY. *See* No. 1340.

1215. OHLY, J. Tin and its occurrence, mineralogy and metallurgy.

Mg. Rep., Vol. 48, 1903, Denver, pp. 487-488, 509-510. Serial.

1st article describes the characteristics of tin and its occurrence in the United States and Alaska.

2d article gives brief history of Temescal (Cal.), ore deposits. Notes foreign localities where mostly produced, describes the ores of tin, and treats of the metallurgy of tin.

1216. PAVLOV, ALEXANDER W. Ueber einige neue Zinnlagerstätten der Vereinigten Staaten von Amerika.

Bull. Mines Ind. or, Nos. 19 and 20, Tomsk, 1904, text figs. 2. (Russian.)

Short description of tin deposits of El Paso (Texas) and Alaska (York Region). (Geol. Centr. Vol. 6, 1905, Leipzig, p. 200.)

PHILLIPS, J. A., and LOUIS, H. *See* No. 1350.

1217. PRATT, J. H. Tin.

Min. Res. U. S. Geol. Surv., 1904 (1905), Washington, D. C., pp. 377-380.

Reviews briefly the production of tin in the United States and in other portions of the world.

UNITED STATES (Continued)

1218. R——, N. Zinn in der Vereinigten Staaten.
Zeitschr. prakt. Geol., 1893, Berlin, pp. 170-171.
Brief notice of tin in South Dakota, California, Virginia. Outlook for tin production in United States not very bright.

1219. Raymond, R. W. Occurrence of tin in the United States.
Trans. Amer. Inst. Mg. Eng., Vol. I, 1871-1873, Philadelphia, pp. 374-375.
Remarks following a paper by T. S. Hunt on tin in Maine, in which the ore from other states is discussed.

Rolker, Chas. M. *See* No. 1357.

1220. Struthers, Joseph, and Pratt, J. H. Tin.
Min. Res. U. S. for 1903 (1904), Washington, D. C., pp. 335-349.
Digest: Neues Jahrb. Min., 1906, II, Stuttgart [Ref.], p. 169.
Tin of South Dakota and Wyoming briefly treated. The Carolina tin belt, its geological location, geology of district, and mineralogical and chemical character of ore, with production, treated by J. H. Pratt.

1221. *See* No. 1203a.

Weeks, Joseph D. *See* No. 1372.

See also Alabama, Alaska, California, Carolinas, Colorado, Georgia, Idaho, Maine, Massachusetts, Michigan, Missouri, Montana, Nevada, New Hampshire, New Jersey, South Dakota, Texas, Virginia, Washington, Wyoming.

VICTORIA

1222. Annual Reports of the Secretary for Mines and Water Supply.
From 1899, Melbourne, Victoria.
Give statistics of production and amount exported and imported annually.

1223. Anonymous. Tin in Australia.
Min. Ind. for 1898, Vol. 7, 1899, New York and London, p. 710.
Tin-bearing gravel 6 to 8 feet deep found near Beenah, Gippsland, Victoria. Plenty of water.

1224. Bracht, J. Report on gold and tin mining at Eldorado, Victoria.
1872, Melbourne,
Not available to the authors.

D'Achiardi, Antonio. *See* No. 1313.

Davies, D. C. *See* No. 1317.

1225. Eddy, William. Special report on the Victoria stream tin deposits.
Mg. Journ. Railw. Comm. Gaz., Vol. 45, 1875, London, p. 1223.
The deposits on Latrobe River, South Gippsland, are from 6 to 30 feet below the surface, and from 6 inches to 3 feet thick all over the flat valley which is from 500 to 1000 feet across. Average assay of concentrates is 65 per cent SnO_2. From deepest parts of flat, sufficient gold exists to pay working expenses. River affords abundant water and power, and there is plenty of timber.

Fawns, Sydney. *See* No. 1320.

VICTORIA (Continued)

1226. GREGORY, J. W. The Mount Cudgewa tin field.

Geol. Surv. Victoria Bull. No. 22, 1907, Melbourne, pp. 1-4.

A preliminary report on recently discovered tin lodes of the Cudgewa district, in Benambra. Alluvial tin has unquestionably wide distribution in some parts of northeast Victoria, but attempts to work the tin-bearing lodes have hitherto failed. The tin-bearing veins of the district occur mostly in the granitic rocks, close to the contact with the schists, but sometimes in the schists.

1227. HERMAN, H. Report on mining at Mitta-Mitta, Eskdale, Tallandoon, and Mt. Elmo.

Special Report Department Mines, 1898, Melbourne, Victoria, pp. 5-6.

Brief article on the geology of the surrounding country and the tin deposits of the districts.

1228. ———. Report on alleged tin and gold discovery at Falls Creek, near Bruthen.

Records of Geological Survey Victoria, Vol. 1, pt. 1, 1902, Melbourne, pp. 70-71, sketch locality plan 1.

Writer visited locality and found nothing done by way of development work since 1880, until two months before his visit, so little real information could be obtained.

Discoverers claim 10 pounds tin obtained on Foggy Creek, and good prospects of tin found in most of gullies tried, also in loam on the slopes of the hills.

1229. KITSON, A. E. The economic minerals and rocks of Victoria.

Special Report Department of Mines, 1906, Melbourne, Victoria, p. 520.

Tin is the second mineral of importance in Victoria, gold occupying the first place.

It occurs as lodes:

1. Thin veins [stockworks] ramifying granitic and porphyritic rocks.
2. Dykes of coarsely crystalline rocks [pegmatite and greisen].
3. Quartz reefs traversing granitic and porphyritic rocks.

As alluvial or stream tin, it is found in the sands and gravels of streams, which have worn down rocks containing tin.

Principal occurrences of the lode tin are at Mt. Cudgewa, Mt. Wills, Pilot Range, and Eskdale in the northeastern district, and Mt. Singapore on Wilsons Promontory, Southern Gippsland.

Stream tin is found in the northeast district, Southern Gippsland, Eastern Gippsland, Western Gippsland, Upper Yarra and other districts.

1230. MURRAY, REGINALD A. F. Report on the geology and mineral resources of Southwest Gippsland.

Rep. Prog. Geol. Surv. Victoria, 1876, Melbourne, p. 171.

No payable tin workings in this district have been mapped. The largest quantity yet obtained was in two small tributaries of the Franklin River. As the deposits are narrow, and do not occupy any considerable length of the creeks, remunerative tin workings are hardly to be hoped for.

1231. MURRAY, R. A. F. Report on the Mt. Wills tin field.

Reports and Statistics of Mines Department for Quarter ended March 31, 1890, Melbourne, Victoria, pp. 15-17, 2 sheets of underground survey of mines, Ballarat East.

Digest: Neues Jahrb. Min., 1891, II, Stuttgart, p. 100.

1232. NEWBERY, J. COSMO. Laboratory report of tin ore.

Rep. Prog. Geol. Surv. Victoria, No. 11, 1875, Melbourne, p. 129.

Brief examination of cassiterite from Franklin, Corner Inlet, and Upper Murray.

VICTORIA (Continued)

NICHOLAS, WM. Localities of minerals which occur in Victoria.

Rep. Prog. Geol. Surv. Victoria, No. 3, 1876, Melbourne, p. 287.

The most important districts where tin is to be found are:

1. Lode tin, Beechworth.

2. Stream tin, Beechworth, Berwick, Bright, Burrowa Creek, Cudgewa Creek, Dry Forest Creek, La Trobe River, Mt. Fatigue, Murray River [upper].

PHILLIPS, J. A., and LOUIS, H. *See* No. 1350.

REYER, EDUARD. *See* No. 1354.

ROLKER, CHAS. M. *See* No. 1357.

ROSALES, HY. Report on Mt. Wills as a gold field and tin field respectively.

Special Report Department Mines, Melbourne, Victoria, 1897, p. 5.

SKENE, A. J., and SMYTH, R. B. Report on the physical character and resources of Gippsland.

1874, Melbourne, pp. 3-65, with map and geol. sect.

"Black oxyd of tin" has been found in basin of River La Trobe, near Mt. Fatigue. Nearly all areas occupied by granite, yield some tin ore. Up to this time little has been done in Gippsland toward mining tin ore.

SMYTH, R. BROUGH. The manner of occurrence of tin ore on the Upper Murray River.

Rep. Prog. Geol. Surv. Victoria, No. 1, 1874, Melbourne, pp. 5-7.

In all granitic tracts, "black oxyd of tin" is found in the beds of the creeks and gullies. Mr. H. Y. L. Brown, of Geological Survey of West Australia, examined the district and gives facts concerning the tin deposits.

———. Tin in Victoria.

Rep. Prog. Geol. Surv. Victoria, 1875, Melbourne, pp. 41, 42, 45.

Author predicts that rich veins of tin ore will be found in the basin of the Mitta-Mitta and the Cudgewa.

Tin ore is found in southwestern and northwestern parts of Gippsland.

STIRLING, JAMES. Report on the tin lodes at Wombat Creek.

Department of Mines, Victoria, Report of Mining Registrars for quarter ended March 31, 1889, Melbourne, pp. 65-67, hachured map 1, pls. 3, figs. 4.

Veins are on a ridge between Mt. Wills Creek [tributary of Big River], and Wombat and Nine Mile creeks, tributary to Mitta River. Tin found in creeks and bench gravels with bismuth and gold. Some lodes were found by government party. The country rock is slate and feldspathic sandstones, of Upper Silurian age, converted into nodular schists and sandstones and highly inclined. Cut by pegmatitite and aplite masses. Tin occurs in pegmatites as stockworks. "Granulitic" lodes traverse the slates. At places there is much tourmaline in the pegmatite. Some granite dikes [ternary] near by are younger than Silurian; thought probably to be Devonian. [No proof given.] Small amount of alluvial tin in Wombat valley, probably indicates that veins have not been exposed long to erosion, and will grow better in depth. Several large diorite dikes have cut the sediments and metamorphosed them. "When the lode or vein intersects certain felsitic sandstones and nodular schists, and the lode is mainly greisen, it is rich in tin, and when the small grains of white feldspar, partly converted into kaolinite are present as additional ingredients, schorl is more abundant." Cassiterite is said to be evenly distributed through some of the lodes. Lodes 1 to 5 feet wide carry 2.9 per cent to 20 per cent tin. Accompanying minerals: tourmaline, wolfram and plumose muscovite in large plates.

VIRGINIA

1239. BENEDICT, WM. DE L. Tin in Virginia.

Min. Ind. for 1892, Vol. I, 1893, New York, pp. 455-456.

Tin known to exist in Virginia about ten years. Found on Irish Creek, Rockbridge County. Ore found in veins in granite. Three veins thus far discovered. Developments consist of open cut extending about 60 feet into face of hill, and a tunnel which penetrates some 40 feet further. Mill has been erected, and experimental tests of ore were made.

1st test: 90 tons assayed 3.44 per cent metallic tin; concentrates from which assayed 43.44 per cent tin.

2d test: 75 tons assayed 3.28 per cent tin, concentrates showing 40.40 per cent tin.

3d test: 125 tons ore, assayed 3.26 per cent tin, concentrates gave 45.07 per cent tin.

1240. BROWN, W. G. On cassiterite from Irish Creek, Rockbridge Co., Virginia.

Amer. Chem. Journ., Vol. 6, 1885, Baltimore, pp. 185-187.

The veins have not been prospected to more than 20 feet in depth, and are much weathered. The cassiterite is brown, from waxy to dark, and the faces are generally dull. Wolframite, arsenopyrite, quartz and mica accompany the cassiterite. Gives a description of crystals and an analysis which shows nearly 0.3 per cent Ta_2O_5.

1241. CAMPBELL, HARRY D. Tin ore (cassiterite) in the Blue Ridge in Virginia.

The Virginias, Vol. 4, 1883, Staunton, p. 151.

Abstract: Amer. Journ. Sci. Arts, ser. 3, Vol. 27, 1884, New Haven, p. 411.

Note on the discovery of tin in eastern corner of Rockbridge County. Cassiterite occurs in quartz veins. Incomplete analysis given.

1242. CROOKES and ROEHRIG. Tinstone, cassiterite.

The Virginias, Vol. 4, 1883, Staunton, p. 169.

Extract from Crookes & Roehrig's Metallurgy.

Short general article.

GARRISON, F. LYNWOOD. *See* No. 1207.

1243. MCCREATH, A. S., and PLATT, FRANKLIN. Description of locality of tin ore, Rockbridge Co., Virginia.

The Virginias, Vol. 4, 1883, Staunton, pp. 150-151.

Not sufficient prospecting had been done to give a good idea of the veins. They occur in crystallines beneath Potsdam No. 1. The ore taken out probably averaged 31.60 per cent tin.

1244. ROBERTSON, W. B. On Virginia tin mines.

Mg. Journ. Railw. Comm. Gaz., Vol. 54, 1884, London, pp. 1221-1222.

Deposits are in high ridges on both sides of Irish Creek, in Rockbridge County. Ore occurs in the form of a "pure and rich cassiterite" permeating quartz veins and mica slate to a width of 40 feet or more. Many crystals are also found. Gives description of the tin veins and outcrops of the district.

1245. ULKE, TITUS. Cash Mine, near Vesuvius, Virginia.

Min. Res. U. S. Geol. Surv., 1893 (1894), Washington, D. C., pp. 178-182.

Development of property hindered by years of litigation. In writer's judgment Cash property warrants development. Mill, said to have cost $30,000, was erected on property several years ago, and about 200 tons of rock, averaging about 3.3 per cent metallic tin were tested. Mineral association and geological occurrence of tin here more closely resembles that of Cornwall than that of any other known tin locality in United States.

VIRGINIA (Continued)

46. WATSON, THOS. L. Mineral resources of Virginia.

The Virginia Jamestown Exposition Commission. 1907, Lynchburg, pp. 567-578.

Gives the location, a short history of the working, and a brief description of the geology of the Irish Creek tin-bearing locality. Most of the article is a transcript of a commercial report upon the region by Major Hotchkiss. Mentions that the occurrence of cassiterite has been reported at Nellys Ford, Nelson County, and at Capron Springs. Gives a bibliography.

47. WHITEHEAD, EDGAR. The tin ore of Virginia.

The Virginias, Vol. 5, 1884, Staunton, p. 38.

Reprinted from "The Advance" (no date), Lynchburg, Va.

A letter dated January 22, 1884, to the "American Artizan," Chicago, in which the Martha Cash tin properties are described. States that there are five known veins, which he thinks will supply the United States with tin. Gives a number of assays of both tin ore and mispickel from the same veins. The latter carried gold and silver up to $255 per ton.

8. WINSLOW, ARTHUR. Tin ore in Virginia.

Eng. Mg. Journ., Vol. 40, 1885, New York, p. 320, sketch maps 3.

Abstract: The Virginias, Vol. 6, 1885, Staunton, p. 168.

Location—western slope of Blue Ridge Mountains, in eastern edge of Rockbridge County.

Description of veins—fissure veins, traversing the granite in all directions. Present developments not sufficient to permit estimate of value nor a prediction as to future of deposits.

WASHINGTON

9. ANONYMOUS. Tin in Washington.

Mg. World, Vol. 26, 1907, Chicago, p. 784, 325 words.

Short account of discovery of tin ore, May 1906, near Spokane, Washington, close to border of Idaho, with brief notes upon the geology and development.

0. COLLIER, ARTHUR J. Tin ore at Spokane, Wash.

U. S. Geol. Surv. Bull. 340, 1908, Washington, D. C., pp. 295-305.

Cassiterite occurs in an elevation known as Silver Hill half an hour's ride from Spokane on an electric road. Cassiterite is in pegmatite accompanied by sillimanite, andalusite and tourmaline. Wolframite and scheelite occur in granite in the same hill.

WESTERN AUSTRALIA

. ANONYMOUS. Tin mines in West Australia.

Mg. Sci. Press, Vol. 70, 1895, San Francisco, p. 39.

A short account of mining operations in the tin fields at Greenbushes, West Australia.

. ———. Greenbushes tin field.

Austr. Mg. Stand., Vol. 17, 1900, Sydney, pp. 247-248.

"Information concerning the situation and the character of these deposits, which are known to contain certain deleterious impurities, difficult to eliminate."

. ———. Tin of Western Australia.

Min. Ind. for 1900, Vol. 9, 1901, New York and London, pp. 638-639.

Mining operations were active during 1900, at Greenbushes. The district is described geologically. About 400 tons of ore were treated at local smelting works during 1900. Specimens of rock from the Cornwall mine assayed 1.79 per cent Sn.

WESTERN AUSTRALIA (Continued)

1254. ———. **Tin in Western Australia.**

Min. Ind. for 1901, Vol. 10, 1902, New York and London, p. 641.

Total quantity of black tin mined during 1901 amounted to 734 tons, valued at £40,000.

1255. ———. **Die Zinnproduction Westaustraliens.**

Zeitschr. prakt. Geol., 1902, Berlin, pp. 209-210.

Taken from "The British Australasian," 1899, p. 330.

1256. ———. **Tin in West Australia.**

Eng. Mg. Journ., Vol. 80, 1905, New York, p. 1071.

Tin ore has been mined for several years on the Greenbushes and Pilbarra mining fields, West Australia. Output of these fields is about 200 tons per annum. Mentions recent discoveries of tin in the Wodgina district, and thinks it possible that within the next few years West Australia will become an important tin producer.

Wodgina district described.

1257. KRUSCH, P. **Die Tellurerze Westaustraliens.**

Zeitschr. prakt. Geol., Vol. 9, 1901, Berlin, pp. 211-217.

Digest translation in Trans. Inst. Mg. Eng., Vol. 22, 1901-1902, London and Newcastle-upon-Tyne, pp. 731-733.

"Quartz porphyry dikes, also occur bearing tinstone with tourmaline and titanite; and the weathering of these dikes has given rise to the Greenbushes stream tin workings."

1258. ———. **Beitrag zur Kenntniss der nutzbaren Lagerstätten Westaustraliens.**

Zeitschr. prakt. Geol., Vol. 11, 1903, Berlin, pp. 378-385, figs. 2.

Digest: Neues Jahrb. Min., 1904, II [Ref.], Stuttgart, p. 242.

Author states that cassiterite occurs:

I. Sparsely in granite.

II. In greisen cutting amphibolite. Wolfram bearing minerals are rare and there are apparently no lithia micas.

III, IV. In alluvial and disintegrated deposits along with muscovite, tourmaline, quartz, garnet, wolframite, tantalum and columbium minerals.

Thinks veins occupy cooling cracks in granite, and that the cassiterite is of pneumatolytic origin though some water is present.

1259. LAPAGE, HERBERT. **Gold and other mineral resources of Western Australia.**

Trans. Fed. Inst. Mg. Eng., Vol. 7, 1894, London and Newcastle-upon-Tyne, p. 510.

"In 1888, Mr. Stinton found some stream tin near Bridgetown on the Blackwood River, which led to rich deposits, extending over about 100 square miles. The tin fields are likely to produce great wealth, if properly worked."

1260. MAITLAND, A. GIBB. **Notes on the Greenbushes tin field.**

Ann. Progr. Rep. Geol. Surv. Western Australia for 1899 (1900), Perth, pp. 7-8 and 15-20, geologic map 1.

Description of claims and geology of Dumpling Gully, Cowan Brook, Bunbury Gully, and adjoining land. The country rock is granite, sometimes gneissoid and containing much tourmaline, largely covered, up to 20 feet thick, with a residual conglomerate. Cassiterite occurs in both alluvial and residual deposits.

1261. ———. **The mineral wealth of Western Australia.**

Western Australian Geol. Surv. Bull. No. 4, 1900, Perth, pp. 84-90.

Introduction treating of tin deposits in general.

Exports of tin ore from Greenbushes and Pilbarra, given. Production of tin throughout Western Australia also given.

WESTERN AUSTRALIA (Continued)

———. Preliminary report on the geological features and mineral resources of the Pilbara gold field.

Western Australia Geol. Surv. Bull. No. 15, 1904, Perth.

Digest: Mg. Mag., Vol. 11, 1905, New York, p. 369.

The tin deposits so far worked are all of detrital origin and have yielded considerable quantities of ore. The ores examined seem to be free from the deleterious constituents which are known to occur in the Greenbushes tinfield.

———. Report on the Wodgina tin field.

Rep. Dept. Mines for 1905 Western Australia, 1906, Perth, pp. 126-140.

Digest: Eng. Mg. Journ., Vol. 80, 1905, New York, p. 1071.

Output of Greenbushes and Pilbara fields about 200 tons of tin per annum. In the new Wodgina field, tin always occurs in granite and pegmatite dikes. In pegmatite dikes tin generally occurs along the sides, though sometimes through the mass. Veins are accompanied by mica and tourmaline.

MAITLAND, A. GIBB, and JACKSON, C. F. V. The mineral production of Western Australia up to the end of 1903.

Western Australia Geol. Surv. Bull. No. 16, 1904, Perth, pp. 56-60.

Brief introduction treating tin deposits in general, followed by a detailed description of the Greenbushes and Marble Bar (Pilbara) districts.

MULHOLLAND, C. A. The Greenbushes tin field, Western Australia.

Austr. Mg. Stand., Vol. 29, 1903, Sydney and Melbourne, pp. 159-160, 192. Serial.

"Begins a description of an interesting field from a scientific point of view, the variety of the deposits and the metallurgical problems to be solved."

Second article treats of mineralogical details in connection with deposits at Greenbushes.

NEWLAND, D. H. Tin in Western Australia.

Min. Ind. for 1902, Vol. 11, 1903, New York and London, p. 595.

Output of tin ore in 1902 was 620 long tons valued at £39,783 as compared with 734 tons valued at £40,000 in 1901. Greenbushes alluvial ore carries 40 to 73 per cent tin and is associated with tantalite. Tin dressing plant has been erected in the district by the government as an aid to the mining industry.

SIMPSON, EDWARD S. Report of the mineralogist and assayer (gold, tin, cobalt).

Annual Progress Report, Geological Survey of Western Australia for 1899 (1900), Perth, pp. 52-54.

Gives notes upon tin ore from Greenbushes field; assays of dressed ore ran from 22.6 to 71.3 per cent, averaging 53.8 per cent.

The reason why some apparently well-dressed ore ran so low was found to be on account of the presence of stibiotantalite. Gives analysis. Notes presence of fine particles of native tin, also zircon, garnet, topaz, and tourmaline.

———. Cassiterite (tinstone). Minerals of economic value.

Western Australia Geol. Surv. Bull. No. 19, 1905, Perth, pp. 53-54.

General account of the properties and characteristics of cassiterite; its mode of occurrence and of troublesome accompanying minerals. Also a few words about stannite.

SIMPSON, EDWARD S., and GIBSON, CHAS. G. The distribution and occurrence of the baser metals in Western Australia.

Western Australia Geol. Surv. Bull. 30, 1907, Perth, pp. 49-76 with map showing distribution.

A compilation of the information upon the various tin claims in each district of the State, with history, geologic conditions, and production.

WESTERN AUSTRALIA (Continued)

1270. "STANNIFER." The Greenbushes tin fields (Western Australia).

Austr. Mg. Stand., Vol. 18, 1900, Sydney and Melbourne, p. 811.

Describes country geologically and geographically, and gives an account of both stream and lode deposits, the prospects of which he considers are good.

1271. TALBOT, —. Wodgina tin field.

Rep. Dep. Mines for 1905, Western Australia, 1906, Perth, pp. 126-128, sketch map 1.

Wodgina is at headwaters of western branch of the Turner River, and within limits of the Pilbara goldfield, about 74 miles from Port Hedland. District bids fair to rise to importance as tin and tantalite producer.

1272. WOODWARD, H. P. Coal and tin in West Australia.

Geol. Mag., n. s., Vol. 6, 1889, London, p. 432.

Thinks discoveries of tin at Bridgetown seems to indicate the biggest thing of the kind that has ever been found. One shaft 18 feet deep will average all the way down about 4 or 5 pounds to the pan. Tin found at surface in sand over area of about 100 square miles.

1273. WOODWARD, HARRY P. Greenbushes tin field (with special reference to the deep leads).

Western Australia Geol. Surv. Bull. 32, 1908, Perth, pp. 1-75, maps 2, pls. 2.

A general description of the district and its mineralogy with detailed descriptions of claims.

WOOLNOUGH, W. G. *See* No. 1649.

WYOMING

ANONYMOUS. *See* No. 985.

1274. AUGHEY, SAMUEL. Minerals of Wyoming territory.

Annual Report of the Territorial Geologist, 1886, Laramie, p. 111.

Tin occurs near Rawhide Buttes in minute quantities, also in small quantities in Silver Crown district.

1275. BENEDICT, WM. DE L. Tin in Wyoming.

Min. Ind. for 1892, Vol. 1, 1893, New York, p. 454.

Area of tin-bearing rocks extends to granite district west and south of Custer City, South Dakota, throughout Nigger Hill district, and into Wyoming.

CHANCE, H. M. *See* No. 1002.

1276. RICKETTS, LOUIS D. Tin in Wyoming.

Annual Report of the Territorial Geologist Wyoming, 1890, Cheyenne, pp. 74-75.

The tin described in this report is in the Black Hills, Crook County. The cassiterite occurs in imperfect crystals [rare], granules, and grains scattered through dikes of quartz, feldspar and mica, which cut the granite country rock. Samples yielded from 2 to 6 per cent metallic tin, and those samples showing no tin minerals from 2 to 4 per cent. Stream tin in fine particles has been found in all gulches that cut the granite dikes.

SADTLER, B. *See* No. 1016.

II. GENERAL BIBLIOGRAPHY

1277. AGRICOLA, GEORGIUS (pen name of George Bauer). Bergwerck buch: darinn nicht allain alle empte' instrument gezeug und alles so zu diesem handel gehörig mit figurem vorgebildet und klärlich beschriben.

1580, Frankfort-am-Mayn.

General treatise on mining and smelting, in which the working of tin ores is mentioned in a number of places.

1278. ANONYMOUS. Notes on tin.

Journ. Soc. Arts, Vol. 1, 1853, London, p. 550.

Briefly treats of bronze articles of Asayria; the Great Polgooth tin mine of Cornwall; metallurgy of tin and the recent discovery of tin at St. Ives, Cornwall. General article.

1279. ———. The position of tin.

The Iron Monger, September 4, 1880, London.

Reprint: Eng. Mg. Journ., Vol. 30, 1880, New York, p. 205.

Tin of the great mining centers discussed and compared.

1280. ———. Tin.

Mg. Sci. Press, Vol. 45, 1882, San Francisco, p. 152.

Tin ore and how it appears. Some plain directions to enable the prospector to distinguish that ore. Character of the rocks in which tin ore is generally found.

1281. ———. Tin.

Eleventh census U. S. 1890, Min. Industries, 1892, Washington, D. C., pp. 249-265.

Tin of Virginia, North Carolina, Georgia, Alabama, Texas, South Dakota and California treated. The tin deposits of the world are discussed in a general manner.

1282. ———. Tin.

Min. Ind. for 1893., Vol. 2, 1894, New York, pp. 607-614.

A general article treating of general conditions.

1283. ———. Tin.

Min. Ind. for 1894, Vol. 3, 1895, New York and London, pp. 521-528.

A general article, prices, statistics, etc.

1284. ———. Tin.

Min. Ind. for 1895, Vol. 4, 1896, New York and London, pp. 569-578.

General prices; the situation in Bolivia, Singkep, Malay Peninsula and Tasmania is reviewed.

1285. ———. Tin.

Min. Ind. for 1896, Vol. 5, 1897, New York and London, pp. 523-532.

General article upon the tin production of the world and the general situation of tin mining. A full page (528) is devoted to South Africa.

1286. ———. Tin.

Min. Ind. for 1897, Vol. 6, 1898, New York and London, pp. 637-648.

Banka, Bolivia, England, Singkep, Spain, Portugal, Straits Settlements, Swaziland and Tasmania are treated briefly.

GENERAL BIBLIOGRAPHY (Continued)

1287. ———. Tin.

Min. Ind. for 1898, Vol. 7, 1899, New York and London, pp. 707-716.

General, markets, statistics.

Tin resources of Australia, Bolivia, China, Congo, Great Britain, Straits Settlements and Tasmania briefly treated.

1288. ———. The occurrence of tin.

Mg. Sci. Press, Vol. 79, 1899, San Francisco, p. 749.

Short general review of tin, localities where found, average yearly output, percentage of output from various countries, manner of occurrence, associated rocks, and kinds of deposits.

1289. ———. Tin.

Min. Ind. for 1899, Vol. 8, 1900, New York and London, pp. 618-628.

Short remarks on the tin-deposits and production of Australia, Banka, France (Montebras) Great Britain and Tasmania.

1290. ———. Tin.

Min. Ind. for 1900, Vol. 9, 1901, New York and London, pp. 635-646.

General article; statistics, short articles on Australasian colonies (New South Wales, Queensland, South Australia and Western Australia), Bolivia, Burmah, Malay Peninsula, Russia (Siberia), and United Kingdom; tin markets; progress of technology (metallurgy, tinning, effect of tin on canned meats, chemical analysis, electrolytic deposition).

1291. ———. Sources of tin supply.

Engineer, Vol. 91, 1901, London, p. 6, 1700 words.

"Discusses the position of tin in the market, and the need of readjusting the balance. Reviews the principal supplies and conditions affecting the output."

1292. ———. Tin.

Min. Ind. for 1901, Vol. 10, 1902, New York and London, pp. 637-646.

Imports, supplies, production; Alaska, New South Wales, Northern Territory, Queensland, South Australia, Tasmania, Western Australia, Bolivia, France. Malay Peninsula, United Kingdom; tin markets in 1901.

1293. ———. The sparse distribution of tin.

Mg. Sci. Press, Vol. 85, 1902, San Francisco, pp. 51-52.

Considered most sparingly distributed metal in common use. Workable deposits of gold cover 1,500,000 square miles, while tin deposits cover less than 125,000 square miles. Gold is, or has been obtained in nearly every country in the world, while tin comes from not more than a dozen different districts.

1294. ———. Tin.

New Volumes of the Encyclopædia Britannica, 10th Edition, Vol. 33, 1902, London, pp. 346-347.

"Primary deposits of tin are in or closely connected with granite or acid eruptive rocks of the same type, associated with tourmaline, fluorspar, topaz, wolfram and arsenical pyrites, and the invariable gangue being quartz." Bolivia is the only exception, "where the tin ore occurs intimately associated with silver ores, bismuth ores and various sulphides, whilst the gangue includes barytes and certain carbonates."

Over 5/6 of the world's tin is from secondary alluvial deposits. Cornwall and Bolivia deposits all in veins. Small portion of that yielded by Australia from veins. Methods of smelting.

1295. ———. Tin in 1902.

Eng. Mg. Journ., Vol. 75, 1903, New York, pp. 29-30.

Good general review of the year.

GENERAL BIBLIOGRAPHY (Continued)

)6. ———. Tin.
Mg. World, Vol. 20, 1904, Chicago, p. 21.
A page of random paragraphs on tin.

)7. ———. The tin position.
Mg. Journ. Railw. Comm. Gaz., Vol. 76, 1904, London, p. 595.
"An editorial reviewing trade conditions and the probable effect of recent discoveries."

)8. ———. Tin.
Min. Ind. for 1904, Vol. 13, 1905, New York and London, pp. 391-400.
Tin mining in United States: Carolinas, South Dakota. Tin mining in foreign countries: Australia, Bolivia, Cornwall, Dutch East Indies, Germany, Malay States. Tin Markets.

)8a. ———. The origin of tin.
Mg. Sci., Vol. 59, 1909, Denver, p. 227, about 190 words.

)8b. ———. Tin.
Mg. Sci., Vol. 59, 1909, Denver, pp. 401-402.
Rather general, reviewing the various localities in United States in which tin has been found, closing with brief account of tin in Cornwall.

)8c. ———. Review of mining in foreign countries.
Eng. Mg. Journ., Vol. 87, 1909, New York, p. 125.
Brief review of tin mining at Mount Bischoff and in Derby districts, Tasmania; New South Wales; Queensland and Northern Territory.

)8d. ———. World's production of tin.
Mg. World, Vol. 32, 1910, Chicago, p. 140.
Statistics showing world's tin production and average prices.

)8e. ———. Short answers to some problems in economic geology.
Mg. Sci., Vol. 61, 1910, Denver, p. 517.
Answering the questions: How does tin ore occur; what does it look like; how may it be recognized in the field? A general article.

BAUER, GEORGE. *See* No. 1277.

)9. BECK, RICHARD. Lehre von den Erzlagerstätten.
1901, Berlin.

———. Nature of ore deposits.
Translated and revised by Walter H. Weed, Vols. 2, 1905, New York.
Contains descriptions of the occurrence and method of mining tin ore, both in alluvial and lode deposits in various parts of the world, and discusses the origin of tin ore.

)0. BECK, R. On the relation between ore veins and pegmatites.
Trans. Geol. Soc. South Africa, Vol. 8, 1905 (1906), Johannesburg, pp. 147-150.
States that tin veins at Zinnwald, Graupen, on the island of Elba, the Etta mine (South Dakota), and Embabaan, South Africa, are pegmatite dikes.
Translated from English by G. Berg in Zeitschr. prakt. Geol., Vol. 14, 1906, Berlin, pp. 71-73.

)1. BENEDICT, W. DE L. Tin.
Min. Ind. for 1892, Vol. 1, 1893, New York, pp. 439-462.
Treats of tin in Cornwall, Australia, East Indies, Malay Peninsula, Bolivia, Mexico and the United States, and the markets during 1902.

GENERAL BIBLIOGRAPHY (Continued)

1302. BERGMAN [—]. Suite de la traduction d'un chapitre de la géographie physique.

Journ. Mines, Vol. 3, No. 16, 1795-1796, Paris, pp. 31-32.
Translated by Guichelin, A.
Short general article on the tin veins of Europe.

1303. BERZÉLIUS, —. Sur la présence d'étain et de cuivre dans les sources sortant d'un terrain volcanique.

C. R. Acad. Sci., Vol. 9, 1839, Paris, pp. 164-165.

1304. BETTANY, G. Papers on the tin trade.

Western Morning News, 1866.
Not available to the authors.

BETTS, ANSON G. *See* No. 1451.

1305. BOERHAAVE, H. A new method of chemistry; including the history, theory, and practice of the art.

1753, London. (Two volumes.)
Translated from the Latin by Peter Shaw. Vol. 1 contains a description of tin and its characteristics; form in which found; metallurgy, and uses, among which medicinal use is mentioned, pp. 98-100. Vol. 2 treats of the chemistry of tin in a brief way, pp. 300-301.

1306. BRANNER, JOHN C., and NEWSOM, JOHN F. Syllabus of a course of lectures on economic geology. Stanford University, 1900.

Outline of a general article on the economic geology of tin deposits, pp. 88-91 and 262.

1307. BROWN, A. SELWYN. The occurrence of tin.

Austr. Mg. Stand., Vol. 16, 1899, Sydney and Melbourne, pp. 369, 385-386, 404-405. Serial.
Describes the tin deposits in various parts of the world and some of their more prominent features.

1308. ———. A review of the world's tin-mining industries.

Eng. Mag., Vol. 34, 1907, New York and London, pp. 325-333.
"Shows how tin deposits are now exploited only in a restricted area and analyzes the steadily growing demand for the metal. The known tin deposits of the world are then reviewed with the idea of determining where and how the increased demand for tin is to be met."

1309. CAMPAGNE, ÉMILE MATHIEU. Les mines, or, argent, fer, cuivre, plomb, étain, zinc, mercure et platine.

1883, Paris.
Not available to the authors.

1310. CHARLETON, ARTHUR G. Tin: describing the chief methods of mining, dressing and smelting it abroad. With notes upon arsenic, bismuth and wolfram.

1884, London and New York, pp. 83, pls. 14.
Briefly describes the geology of the tin deposits of Altenberg and Zinnwald, Saxony, and Abertham, Bohemia, but gives more attention to methods of mining, dressing and smelting.

GENERAL BIBLIOGRAPHY (Continued)

1311. CLARKE, FRANK W. The data of geochemistry.

U. S. Geol. Surv. Bull. 330, 1908, Washington, D. C., pp. 591-595.

Treats the principal known minerals of tin; the artificial production of cassiterite; the solubility of cassiterite; rocks in which tin ores occur; and the associated minerals. Many bibliographic references.

1312. COTTA, BERNARD VON. A treatise on ore deposits.

Translated from 2d German Edition by F. Prime, 1870, New York, pp. 553.

Treats of tin deposits; modes of occurrence; relation of the rocks to the ore deposits; distribution of ores in deposits; tin of Germany, France, Cornwall and Finland.

1313. D'ACHIARDI, ANTONIO. I metalli loro minerali e miniere.

Vol. II, 1883, Milan, pp. 522-559.

Gives a general treatment of tin as a metal and then of its minerals, cassiterite and stannite, and accompanying minerals. Gives descriptions of deposits in Italy, Great Britain, France, Spain, Portugal, Germany, Austria, Siberia, China, Japan, India, Siam, Malay Peninsula, East Indies, Queensland, Victoria, Tasmania, Bolivia and the United States followed by generalizations upon the deposits.

1314. DAUBRÉE, A. Mémoire sur le gisement, la constitution, et l'origine des amas de minerai d'étain.

Ann. Mines, 3d ser., Vol. 20, 1841, Paris, pp. 65-112.

Extrait par l'auteur, C. R. Acad. Sci., Vol. 12, 1841, Paris, pp. 886-890.

Extrait: Bull. Soc. Geol. France, 1st ser., Vol. 12, 1841, Paris, pp. 393-401.

Also, Edinburgh, New Philos. Journ., Vol. 32, 1842, Edinburgh, pp. 154-159.

Translation, Mg. Journ. Railw. Comm. Gaz., Vol. 12, 1842, London, pp. 9-10.

"In the above memoir Daubrée describes the mode of occurrence of tin ore in certain stockworks in Saxony, Bohemia, Cornwall and France. He shows that, after quartz, the minerals most frequently accompanying tin ore are compounds containing fluorine, principally fluosilicates (lepidolite, topaz), sometimes fluophosphates (apatite) and fluorides (fluorspar). The element boron (tourmaline, axinite) is often abundant. The other elements most commonly met with are tungsten, molybdenum, phosphorus, arsenic and iron. Daubrée draws the conclusion that the tin ore, fluorine compounds, and borosilicates owe their origin to the same set of reactions. He supposes that the tin, tungsten, molybdenum, boron, phosphorus, and some of the silicon came up through fissures from some deep seated source as fluorides. Finally, Daubrée suggests that the present condition of the stockworks, which consist of quartz, tin ore, silicates, fluosilicates and borosilicates, resulted from the reactions of these fluorides, probably in the presence of water, on the enclosing rocks."—C. Le Neve Foster.

1315. ———. Ueber Zusammensetzung und Entstehung der Zinnerzlagerstätten.

(From Dufrénoy's report to the Paris Academy, 1841.) Institut Vol. 9, 1841, Paris, pp. 365-366.

Abstract: Neues Jahrb. Min., 1842, Stuttgart, p. 609-610.

General discussion as to the manner in which tin occurs in different deposits of the world.

1316. ———. Études synthétiques de géologie expérimentale.

1879, Paris, pp. 24, 37, 67-68, 113, 594.

Treats of tin oxide in veins, the artificial production of tin oxide, its presence in kaolin in Allier, occurrence of tin in Central France, the occurrence of tin in an altered lead in Bourbonne, also the presence of tin in meteorites.

GENERAL BIBLIOGRAPHY (Continued)

1317. DAVIES, D. C. A treatise on metalliferous minerals and mining.

Published by Crosby Lockwood & Co., 1880, London, pp. 162-186, figs. 64-78.

Treated under heads: General description; modes of occurrence; alluvial mining in Banca, in the Malay Peninsula; tin ore deposits of Bohemia and Saxony; France and Sweden; tin in the British Isles, importance and antiquity of the industry; tin of Bolivia, Queensland, New South Wales, Victoria and Tasmania.

1318. DAY, DAVID T. Tin.

Min. Res. U. S. for 1885, U. S. Geol. Surv., 1886, Washington, D. C., pp. 370-385.

Treats of American and foreign tin resources and production in a very general way.

1319. ———. Tin.

Min. Res. U. S. for 1889 and 1890, U. S. Geol. Surv., 1892, Washington, D. C., pp. 119-123.

Brief review of developments made during 1890 in California, South Dakota and Virginia. Census statistics.

1320. FAWNS, SYDNEY. Tin deposits of the world.

Published by Mg. Journ., Railw. Comm. Gaz., 1905, London, pp. 1-9 and 1-204.

Reviewed by Hess, Frank L.: Econ. Geol., Vol. 1, 1906, Lancaster, pp. 500-502.

Chap. 1. The common forms of stanniferous minerals and the early history of tin mining, p. 1-7.

Chap. 2. Description of tin deposits, pp. 7-18.

Chap. 3. Alluvial tin deposits of the Malay Peninsula, pp. 18-31.

Chap. 4. Alluvial tin deposits of Banca, Billiton, Siak, Sumatra, Siam, and British Burma, pp. 31-45.

Chap. 5. Alluvial tin mining, pp. 45-56.

Chap. 6. Tin lode deposits in the Malay Peninsula, pp. 56-68.

Chap. 7. Tin deposits of New South Wales, pp. 68-83.

Chap. 8. Tin deposits of Queensland, pp. 83-90.

Chap. 9. Tin deposits of Tasmania, pp. 90-105.

Chap. 10. Tin deposits of Western Australia, Northern Territory of South Australia, New Zealand and Victoria, pp. 105-112.

Chap. 11. Tin deposits of Bolivia, pp. 112-125.

Chap. 12. Tin deposits of Cornwall, pp. 125-139.

Chap. 13. Tin deposits of Northern Nigeria, Transvaal, Swaziland and Congo Free State, Japan, Greenland, Finland, China, Korea, Siberia, pp. 139-149.

Chap. 14. Tin deposits of Central Europe, Spain, Portugal, France, Italy, Scotland, Ireland, Mexico, United States and Alaska, pp. 149-165.

Chap. 15. Mount Bischoff tin mine, pp. 165-175.

Chap. 16. The Dolcoath tin mine, pp. 175-186.

Chap. 17. Tin crushing and dressing machinery, pp. 186-199.

Chap. 18. Dredging for tin, pp. 199-207.

Chap. 19. Methods of tin assaying, pp. 207-224.

Chap. 20. Statistics of tin production, pp. 224-233.

Bibliography of 54 articles, pp. 233-236.

The most complete compilation on the subject to date, but contains many inaccuracies.

1321. FEUCHTWANGER, LEWIS. Tin and its applications.

Iron, Vol. 5, n. s., 1875, London, p. 179.

General article, treating briefly; early history of tin, its properties, its manner and form of occurrence, uses, localities, where found, metallurgy and chemistry.

1322. FOULLON, H. Ueber Zinnerze und gediegenen Wismuth.

Verh. k. k. geol. Reichs., No. 7, 1884, Wien, pp. 144-148.

An account of the occurrence of tin in Zinnwald, New South Wales, Tasmania, Chile, Bolivia and Cornwall.

GENERAL BIBLIOGRAPHY (Continued)

1323. Fuchs, E., and de Launay, L. Traité des gîtes minéraux et métallifères.

Vol. 2, 1893, Paris, pp. 101-158.

Treats of the uses and statistics of tin, tin veins and general geology; tin of Cornwall, Germany, France, Spain and Portugal, Italy, Bolivia, Malay Peninsula, Banka and Billiton and Australia.

1323a. Good, T. The world's tin supply.

Cassier's Magazine, Vol. 34, 1908, New York, pp. 483-487.

By arguing from wrong and insufficient data, concludes that there is no danger of the world's tin supply giving out in the near future.

1324. Graham, Walter. Tin, tin plate and tin alloys.

Brit. Mfr. Indust., Vol. 1, 1876, pp. 155-172.

Treats subject under following heads:

Early history of Cornwall tin; discovery of tin in Misina and Bohemia; properties of tin; description of tin ore and its occurrence; reduction of ore; refining; uses of tin in manufactures; tin-plate working; tin alloys; uses in the arts.

1325. Gray, John W. Some notes concerning tin.

Mg. Sci. Press, Vol. 88, 1904, San Francisco, pp. 197-198, 2000 words.

Concerning the location of the tin deposits of the world, method of extraction, the distribution and production of the metal.

1326. Guenther, Richard. Tin production of the world.

Monthly Consular Reports, State Department, March, 1905, Washington, D. C., p. 32.

Quotes "German returns" giving production of 1903 as 93,093 tons. (Kind of tons not stated.) Refers to "considerable deposits" in South Dakota, Wyoming, South Carolina and North Carolina.

1327. Henwood, Wm. J. Observations on metalliferous deposits.

Trans. Roy. Geol. Soc. Cornwall, Vol. 8, 1871, Penzance.

Treats of tin as an occasional constituent of rocks; of the derivation of stream tin, and why it is superior to lode tin in purity; extraction of tin ore by different classes of labor; the association of stream tin with gold in Wicklow and Banca, and with gold and platinum in Australia; of Roman remains in partially worked stream beds; and of the association of tin with fluorine.

1328. Hess, Frank L. Review of "Tin deposits of the world," by Sydney Fawns.

Econ. Geol., Vol. 1, 1906, Lancaster, pp. 500-502.

1329. Hess, Frank L., and Graton, L. C. The occurrence and distribution of tin.

Contributions to Economic Geology, 1904, U. S. Geol. Surv. Bull. 260, Washington, D. C., pp. 161-188.

Digest in Mg. Mag., Vol. 11, 1905, New York, p. 559.

A short compilation of data upon most of the known occurrences of tin, with a bibliography of ninety-two works.

1330. Hopkins, Evan. On the superficial production of gold, oxide of tin, etc., or alluvial metalliferous deposits.

H. English's Min. Almanac, 1849, pp. 192-197.

Not available to the authors.

GENERAL BIBLIOGRAPHY (Continued)

1331. HUNT, T. S. Remarks on the occurrence of tin ore at Winslow, Me.
Trans. Amer. Inst. Mg. Eng., Vol. 1, 1871-1873, New York, pp. 373-374.
Remarks by Prof. Silliman and R. W. Raymond, pp. 374-375.
Besides Winslow, Paris and Hebron are mentioned as having tin deposits.
In the discussion, a very brief and general review of tin deposits is given to afford comparison with the deposits under discussion.

1332. INGALLS, W. R. Tin.
Min. Ind. for 1905, Vol. 14, 1906, New York and London, pp. 534-556.
Treats of the tin deposits of the world.

1333. JARS, GABRIEL. Voyages metallurgiques.
2 Vols., 1774-1781, Lyon.
Not available to the authors.

1334. KALB, COURTNAY DE. Relation of tin to trap dikes.
Eng. Mg. Journ., Vol. 45, 1888, New York, p. 435.
States that he has never heard of tin in greisen or granitic rocks, but always in quartz veins close to basaltic dikes. States that small amounts of cassiterite have been found in Haywood and Henderson counties, North Carolina.

1334a. LAKES, ARTHUR. Tin. History, use.
Mg. World, Vol. 30, 1909, Chicago, pp. 1170-1171. 1 fig.
"The geology and mineralogy, history, uses and sources of tin are treated. The object of this article is to familiarize the reader with tin mining."

1335. LAPPARENT, A. DE. Traité de géologie.
1883, Paris, pp. 1172-1177, fig. 1.
Treats in a general way tin deposits in Saxony, Bohemia, Cornwall, France, East Indies, Australia, China, Mexico and Italy.

1336. LEIBIUS, ADOLPH. Remarks on tin ore and what may appear like it.
Trans. Roy. Soc. New South Wales, Vol. 6, 1872 (1873), Sydney, pp. 73-74.
Description of minerals that may be mistaken for tin ore, and ways of differentiating them.

1337. LINDGREN, WALDEMAR. Metasomatic processes in fissure-veins.
Trans. Amer. Inst. Mg. Eng., Vol. 30, 1900 (1901), New York, pp. 619-626.
Topaz-cassiterite veins. Altenberg and Zinnwald, Saxony, Mt. Bischoff, Tasmania.
Same paper also published with Pošepný's "Genesis of Ore Deposits," pp. 540-545 (2d Ed.). Uses these tin deposits as examples of metasomatism.

1338. LOCK, C. G. WARNFORD. Economic mining.
1895, New York, pp. 622-635, fig. 1.
Tin mining districts treated, rocks in which tin occurs described, yield, method of working, profit. Cornish tin districts, Spain, India, Dutch East Indies, Tasmania, Australia, Queensland, New South Wales, Mexico, Bolivia, South Africa. Treatment of ores. Commerce.

1339. LOOS, D. DE. Tin.
1888, Haarlem.
Not available to the authors.

1340. LOUIS, HENRY. The production of tin.
Mg. Journ. Railw. Comm. Gaz., Vol. 69, 1899, London. A series of articles.
Pp. 516, 547. On tin in general; history, mode of occurrences, manner of working.
Pp. 581, 611. Cornwall.
P. 643. Central Europe, Iberian Peninsula, Finland, remainder of Europe, Africa.

GENERAL BIBLIOGRAPHY (Continued)

P. 676. Asia, Malay Peninsula.

P. 707. Shipments of tin from Straits Settlement, production of tin returned as metal in Federated Malay States.

P. 736. Malay Archipelago, remainder of Asia.

P. 771. Australia, New South Wales, Tasmania, Queensland.

P. 804. Mexico; United States, South America; world's production.

Extract: Zeitschr. prakt. Geol., 1899, Berlin, pp. 287-293.

Reprinted in pamphlet form, 1899.

A good synopsis of the mining, history, distribution, occurrence and production of tin throughout the world.

1341. MacAlister, Donald A. Tin and tourmaline.

Quart. Journ. Geol. Soc. London, Vol. 59, 1903, London, pp. 53-54.

Abstracts: Neues Jahrb. Min., 1905, I (Ref.), Stuttgart, p. 101.

Geol. Mag. n. s., decade 4, Vol. 10, 1903, London, p. 46. Abstract of paper read before the society.

Cassiterite rarely occurs without tourmaline, although the latter is found without the former. A discussion as to causes of deposition of the oxide of tin follows.

1342. Majendie, Ashurst. Contributions towards a knowledge of the geological history of wood-tin.

Trans. Roy. Geol. Soc. Cornwall, Vol. 1, 1818, London, pp. 237-239.

Short description of wood-tin and its manner of occurrence. Ascribes it to vein formation.

1343. Massart, Alfred. Minerales de estaño en los terrenos secundarios.

Rev. Min., ser. B, Vol. 2, 1876, Madrid, p. 87.

1344. Merrill, Geo. P. Our sources of tin.

Sci. Amer. Suppl., No. 830, Vol. 32, 1891, New York, pp. 13257-13258.

"World's supply of tin amounts to some 50,000 and odd tons annually, of which nearly one-half comes from Malayan Peninsula and adjacent islands, 1/6 from Cornwall, 1/9 from Australia and the remainder from scattering sources, including Saxony and Bohemia, Finland, Spain, Tasmania, Bolivia and Mexico. United States has until recently produced very little."

1345. Meyers, —. Konversations-Lexikon, Vol. 17.

1897, Leipzig and Wien, pp. 1038-1040.

General article on tin.

1346. Newland, D. H. Tin.

Min. Ind. for 1902, Vol. 11, 1903, New York and London, pp. 584-597.

Review of tin deposits in general:

United States, Alaska, Bolivia (by J. B. Minchin), Malay States, New South Wales, Queensland, Tasmania, United Kingdom, Western Australia; general remarks regarding tin markets.

1347. ———. Tin.

Min. Ind. for 1903, Vol. 12, 1904, New York and London, pp. 325-339.

Treats tin production in Alaska, Australia, Austria, Bolivia, Germany, Malay States, Mexico, South Africa, and the United Kingdom. Reviews the New York and London tin markets during 1903, and the progress of technology.

1348. Nicholls, —., Dr. Some further observations towards composing a natural history of mines and metals.

Philos. Trans. Roy. Soc. London, No. 403, Vol. 35, 1728, London, p. 408.

Abridged Ed. Vol. 7, 1809, pp. 249-250.

A general article describing the crystals of cassiterite and the manner in which the ore occurs.

GENERAL BIBLIOGRAPHY (Continued)

1349. PHILLIPS, J. ARTHUR. Ore deposits.

1884, London, pp. 109, 230, 301, 310, 317, 353, 375, 382, 398, 435, 443-445, 473, 481, 491, 505, 565, 610, 621.

The tin deposits of the world are treated in a general way under the headings of the different countries.

1350. PHILLIPS, J. ARTHUR, and LOUIS, HENRY. A treatise on ore deposits.

1896, London.

Tin deposits in the following countries treated:

Australia, Austria, England, France, Finland, Germany, Hungary, India, Italy, Malaysia, New South Wales, Portugal, Queensland, Russia, South America, Spain, Tasmania, United States and Victoria.

In this 2d Edition Phillips' original work is rewritten and enlarged by Henry Louis.

1351. POŠEPNÝ, FRANZ. The genesis of ore deposits.

Published with other papers on ore deposits by the Amer. Inst. Mg. Eng., 1902, New York (2d Ed.).

Cornwall pp. 139-140; placer deposits pp. 158-160.

Quotes tin deposits to draw general conclusions concerning the deposition of ores.

PRATT, JOSEPH HYDE, and STERRETT, DOUGLASS. *See* No. 252.

1352. PRYCE, WM. Mineralogia Cornubiensis: a treatise on minerals, mines and mining to which is added an explanation of the terms and idioms of mines.

1778, London, folio, pp. 331, pls. 7, portrait of author, tables 2.

1353. REILLY, —. Sur les gisements de l'étain, au point de vue géologique.

C. R. Acad. Sci., Vol. 104, 1887, Paris, pp. 600-602.

1354. REYER, EDUARD. Zinn. Eine geologisch-montanistisch-historische Monographie.

1881, Berlin, pp. 248, bibliography.

Résumé of the geological, mineralogical and metallurgical conditions in, as well as the history of different tin producing regions.

1355. ———. Geologie des Zinnes.

Oest. Zeitschr. Berg. Hütt. Vol. 29, 1881, Wien, pp. 9-11, 24-27, 33-34, sketches 4.

1. Die Wäschen.
2. Zinnbergbaue.
3. Die Genesis des Zinnerzes.

1356. RICHTER, KARL. Zink, Zinn und Blei.

1883, Wien, Pest, Leipzig.

The characteristics and working of these metals, their relations to each other and to other metals.

1357. ROLKER, CHARLES M. The production of tin in various parts of the world.

16th Ann. Rep., Dir. U. S. Geol. Surv., 1894-1895, pt. 3, 1895, Washington, D. C., pp. 458-538.

Review of the tin mines of the world. Includes statistics and notes on the occurrence of tin in Maine, Virginia, North Carolina, Alabama, Texas, South Dakota, and California.

GENERAL BIBLIOGRAPHY (Continued)

1358. SANDBERGER, F. Ueber das Vorkommen des Zinn in Silicaten.

Sitz. Kön. bayer. Akad. Wiss., Vol. 8, 1878, München, pp. 136-139.
Digest: Neues Jahrb. Min., 1878, Stuttgart, pp. 748-749.

1359. SCHULTZ, F. W. Solder, its production and application with a brief history of tin and lead.

Unpaged. About 23 pages including Chapters III to VI are devoted to tin. A brief history of the use of tin, a summary of its production, and a somewhat inaccurate description of the localities producing it, are given.

1360. SEDGWICK, ADAM. Remarks on the structure of large mineral masses, and especially on the chemical changes produced in the aggregation of stratified rocks during different periods after their deposition.

Trans. Geol. Soc. London, Vol. 3, 1829, London, p. 483.
States that besides occurring along joints tin deposits occur as segregations from granite.
Short paragraph.

1361. SEXTON, A. HUMBOLT. Notes on tin.

Mech. Eng., Vol. 21, 1908, London, pp. 43-46, 99-101, 175-177, 239-240, illus.
Serial. First part. "The present number considers its physical and chemical properties, uses, value; tin minerals and ores, their distribution," etc.
Second part. Mining and ore dressing. "The methods of working alluvial tin deposits are described and then the methods of concentrating tin ore are outlined. Notes regarding crushing, magnetic separation, and wet concentration given."
Third part. Smelting. "Discusses different methods of smelting tin. Reverberatory method as used in Cornwall and Singapore described; also shaft furnace smelting and Chinese methods."
Fourth part. Refining. "Discusses the refining of the metal and the process used in Cornwall."

1362. SMYTH, WARINGTON. Address of the president.

Trans. Roy. Geol. Soc. Cornwall, Vol. 10, 1887, Penzance, pp. XVII-XX.
Treats of tin occurrence, mining and production of Queensland, New South Wales, Banca, Billiton and the East Indies in a very brief way.

1363. STEVENS, CHAS. Tin; history and production.

Austr. Mg. Stand., Vol. 28, 1902, Sydney and Melbourne, pp. 543-544, 580, 2700 words.
"Reviews the history of this mineral, giving the sources of supply, the formation of the lodes, etc."

1364. STRUTHERS, JOSEPH, and PRATT, JOSEPH HYDE. The production of tin in 1903.

Min. Res. U. S. for 1903, U. S. Geol. Surv., 1904, Washington, D. C., pp. 335-349.
Treats briefly of the Black Hills deposits; the Alaskan deposits (taken from A. J. Collier's Bull. 229, U. S. Geol. Surv.); the Carolina tin belt; the market conditions, especially in the United States; and the world's production.

1365. TASSIN, WIRT. Descriptive catalogue of the collections of gems in the U. S. National Museum.

Ann. Rep. Board Reg. Smithsonian Institution, 1902, Washington, D. C., p. 494.
Cassiterite is described.

GENERAL BIBLIOGRAPHY (Continued)

1366. URE'S Dictionary of Arts, manufactures and mines.
7th Ed., Vol. 3, 1878, London, pp. 998-1009, figs. 12.
General article on tin. Description of minerals, localities where found, method of treatment of ore.

1367. VAN HISE, CHARLES RICHARD. A treatise on metamorphism.
Monogr. U. S. Geol. Surv., Vol. 47, Washington, D. C., pp. 1053-1055, 1058, 1127-1128.
Treats of the processes of deposition of tin ores.

1368. VOGT, J. H. L. Ueber die durch pneumatolytische Processe an Granit gebundenen Mineral-Neubildungen.
Zeitschr. prakt. Geol., 1894, Berlin, pp. 458-465.
Exposition of the author's and others' views upon the deposition of tin and other minerals connected with granite intrusions.

1369. ———. Zinnstein-Gang gruppe.
Zeitschr. prakt. Geol., 1895, Berlin, pp. 145-156, figs. 5.
Most of the tin deposits of the world are treated. A general, genetic discussion is given.

1370. ———. Problems in the geology of ore deposits.
Trans. Amer. Inst. Mg. Eng., Vol. 31, 1902, New York, pp. 134-136.
Also in Genesis of Ore Deposits, Amer. Inst. Mg. Eng., pp. 639 and 657 (2d Ed.).
Cassiterite and apatite veins. Points out that the former are always connected with acid igneous rocks, while the apatite veins are connected with gabbro.

1371. WALKER, CHAS. H. Hints to aid the identification of stream tin.
Mg. Sci. Press, Vol. 90, 1905, San Francisco, pp. 188-189.
"Several tests that may be used by the miner are given: most common colors are black, brown, red and yellow. A sapphire will easily scratch the smooth surface of a pebble or crystal of stream tin, but a quartz crystal will only make a scratch when a heavy pressure is applied. . . . . Extremely hard, very heavy, unmetallic appearance, uninteresting, and unsuggestive of value."

1372. WEEKS, JOSEPH D. Tin. Its history, production and statistics.
Amer. Mfr. Iron World (Tin-plate Suppl.), Vol. 50, 1892, Pittsburg, pp. 11-33. Illus.
Gives a history of tin; describes tin ores; their occurrence; deposits of Cornwall, with short notes upon other deposits of the world; methods of mining, smelting and refining; and gives statistics of production. Also treats of the tin plate industry, defines technical terms and describes machinery used.

III. HISTORY

1373. ANONYMOUS. Tin trade of the seventeenth century.
Mg. Journ. Railw. Comm. Gaz., Vol. 19, 1849, London, p. 400.

———. *See* Nos. 310 and 611.

1374. APPLETON, W. S. The earliest American coin.
American Journal of Numismatics, Vol. 5, 1870, Boston, pp. 25-27, fig. 1.
Short description and illustration of the anchor shaped piece of tin used by the Aztecs as money.

1375. BAPST, GERMAIN. Les métaux dans l'antiquité et au moyen âge. L'étain.
1883, Paris.
Not available to the authors.

1376. ———. Études sur l'étain, dans l'antiquité et au moyen âge.
1884, Paris.
Not available to the authors.

1377. BATTEN, JOHN. The stannaries act, 1869, with notes.
1873, London.
Not available to the authors.

1378. BAUDOT, F. Histoire, conditions géologiques et principaux usages de l'étain.
Bull. Soc. Indust. min., ser. 3, Vol. 1, livre 1, 1887, Saint Etienne, pp. 335-343.

1379. BERTHELOT, P. Métaux et minéraux provenant de l'antique Chaldée. Sur les origines de l'étain dans le monde ancien.
C. R. Acad. Sci., Vol. 104, 1887, Paris, pp. 265-271.

1380. BIBLE.
Numbers 31: 22. Tin found among spoils of Midianites in days of Moses.
Ezekiel 27: 12. Tin is mentioned as abundant in Phœnicia in early ages, and as a current commodity of commerce at Tyre, although not produced there.

1381. BORLASE, WILLIAM COPELAND. Observations on the ancient and present state of the island of Scilly, and their importance to the trade of Great Britain.
1756, Oxford, pp. 72-78.
Discusses the question of where the Phœnicians got their tin. Historical.

1382. ———. Antiquities, historical and monumental of the county of Cornwall, etc.
1769, London (2d Ed.), pp. 29-30.
Treats very briefly of the early Grecian and Phœnician tin trade.

1383. ———. Historical sketch of the tin trade in Cornwall, from the earliest period to the present day.
1874, Plymouth, pp. 7-72. Illus.

HISTORY (Continued)

1384. BURNARD, ROBERT. Antiquity of mining in Dartmoor.

Ann. Rep. Trans. Plymouth Inst., Devon and Cornwall Nat. Hist. Soc., Vol. 11, 1890-1894 (1894), Plymouth, pp. 85-112, figs. 5.

From an examination of evidence to be found in Cornwall, and also from early writers, the author reaches the conclusion that the "probable antiquity of the Bronze Age in Britain is from three to four thousand years, and the consequent production of tin in Devon and Cornwall must be as old."

A number of old documents dealing with the laws and customs of the Stannaries in Devon are reprinted.

CHURCH, A. H. *See* No. 620.

1385. COLLINS, J. H. Seven centuries of tin production in the west of England. Read March, 1891.

Trans. Mg. Ass. Inst. Cornwall, Vol. 3, 1892, Camborne, pp. 173-184, discussion, pp. 184-196.

Historically interesting. Review of English tin production from early records.

1386. D——, C. H. The "Cornwall" of France; ancient tin works.

Mg. Journ. Railw. Comm. Gaz., Vol. 36, 1866, London, p. 210.

A brief review of the writings of M. Simonin and M. Mallard on the subject of the working of the ancient tin mines at Limousin and La Marche, thought to have been worked by the Gauls.

1387. DAVY, L. Sur l'ancienneté probable de l'exploitation de l'étain, en Bretagne.

C. R. Acad. Sci., Vol. 125, 1897, Paris, pp. 337-339.

1388. DUFRENÉ, HECTOR. Étude sur l'histoire de la production et du commerce de l'étain.

Ann. Gén. Civ., Vol. 9, 1880, Paris, pp. 649-681, 793-826.

Not available to the authors.

1389. EDMONDS, RICHARD. On the Phœnician tin trade in Cornwall, with remarks on the great irruption of the sea in the eleventh century, sand-hillocks, "raised beaches," the causeway between Marazion and St. Michael's Mount; and the origin of the names Marazion, Market Jew, Iktin and Britain.

Ann. Rep. Trans. Plymouth Inst. Devon and Cornwall Nat. Hist. Soc., Vol. 3, 1868, Plymouth, pp. 17-37.

Historical.

1390. FLOWER, PHILIP WM. A history of the trade in tin; a short description of tin mining and metallurgy; a history of the origin and process of the tin plate trade, and a description of the ancient and modern process of manufacturing tin plates.

Extracts from "Boston Herald," Sci. Amer. Suppl., Vol. 32, 1891, New York, pp. 13280-13281.

1391. GÄTZSCHMANN, M. F. Beiträge zur Geschichte des Freiberger Zinnbergbaues.

Berg. Hütt. Zeit., Vol. 3, 1844, Leipzig, pp. 3-8, 63-68, 125-131, 164-171, 232-243.

1392. GEORGE, R. D. Mining and use of metals by the ancient Egyptians.

Pop. Sci. Mo., Vol. 67, 1905, New York, pp. 696-697.

Mentions a bronze article found dating back to Papi, a Pharaoh of the sixth dynasty, about 2500 B. C.

HISTORY (Continued)

1393. GREATHEAD, SAMUEL. On the knowledge and commerce of tin among ancient nations.

Trans. Roy. Geol. Soc. Cornwall, Vol. 2, 1822, Penzance, pp. 359-365.

Article tracing the use of tin among the ancient nations, and also drawing conclusions as to where it was mined.

1394. HANKS, HENRY G. Tin.

Ann. Rep. California State Min. 1880 (1881), Sacramento, pp. 31-32.

Short history of the discovery of the tin deposits of the world. Tin is mentioned as occurring in "veins of rich tin ore" in San Bernardino County, California.

1395. HAWKINS, C. Observations on the tin trade of the ancients, in Cornwall and on the "Ictis" of Diodorus Siculus.

1811, London.

Historically interesting.

1396. HAWKINS, JOHN. On the state of our tin mines at different periods, until the commencement of the 18th century.

Trans. Roy Geol. Soc. Cornwall, Vol. 4, 1838, Penzance, pp. 70-94.

A historical recount of the tin mines of England beginning with the period of the Romans.

1397. HUNT, ROBT. Tin mining in Cornwall and its traditions.

Good Words, 1867, London, pp. 126-131.

Historical, treating of the traditions and early history of Cornish tin mining.

HUNT, ROBERT. *See* Nos. 412 and 413.

1398. JAMES, HENRY. Note on the block of tin dredged up in Falmouth harbor.

45th Ann. Rep. Roy. Inst. Cornwall, 1863, Truro, pp. 29-33, pls. 4.

Considering the peculiar form of this block of tin, its weight and the place where it was dredged up, it appears to throw light upon the still vexed question of the locality of the Ictis of Diodorous. Quotations from passages of Diodorous, relative to tin trade of Britain.

1399. ———. On ancient Phœnician tin trade.

Mg. Journ. Railw. Comm. Gaz., Vol. 34, 1864, London, p. 65.

Abstract of address delivered at Southampton Polytechnic Institution.

1400. KENDRICK, JOHN. Phœnicia.

1855, London, pp. 212-223.

Treats of the early Phœnician tin trade with Britain and speculates as to the Cassiterides.

1401. LEWIS, GEORGE CORNEWALL. An historical survey of the astronomy of the ancients.

1862, London, pp. 450-457.

Quotes many of the ancient writers on Phœnician trade, and comes to the conclusion that tin was supplied in early times to nations in the east of the Mediterranean by the overland route across Gaul, and that the Phœnician ships got it at the mouth of the Rhone, without sailing as far as Britain. Some tin may have been obtained from Gades.

1402. LEWIS, GEORGE RANDALL. The Stannaries: A study of the English tin miner.

1908, Boston, pp. 299, Bibl.

"The author aims to give, on the basis of the available printed and manuscript sources, an account of English tin mining and miners from the twelfth to the eighteenth centuries."

HISTORY (Continued)

LOUIS, HENRY. *See* No. 1340.

1403. MACLEAN, JOHN. Stannary roll 34th, Edward I (1305-1306) with introductory remarks thereon, and on other similar rolls.

Journ. Roy. Inst. Cornwall, Vol. 3, No. 12, 1871, Truro, pp. 238-241.

Remarks on same, pp. XXVI-XXVII.

Extracts from MSS. showing the magnitude of tin mining in Cornwall during the fourteenth century.

1404. ———. The tin trade of Cornwall in the reigns of Elizabeth and James compared with that of Edward I.

Journ. Roy. Inst. Cornwall, Vol. 4, 1874, Truro, pp. 187-190.

Brief account of tin "coined" between years 1305-1607.

1405. NAPIER, CHAS. R. G. On the localities from whence the gold and tin of the ancients were derived.

Rep. Brit. Ass. Adv. Sci., 45th meeting 1875, Bristol, pt. 2, 1876, London, p. 177 (Abs.).

Tin was known, at least 1500 years B. C. Britain, Brazil and Sumatra mentioned as tin supplying countries for ancients.

1406. PATTISON, S. R. On ancient and modern tin-works in France.

Journ. Roy. Inst. Cornwall, Vol. 2, October, 1867, Truro, pp. 343-345.

Author arrives at following conclusions, some as historical facts, the rest as probabilities:

(1) At one epoch the provinces of Limousin and Marche possessed at Montebras and Vaulry important tin mines.

(2) Similar works were probably attempted throughout these two Provinces, which accounts for the numerous remains of open works now visible.

(3) Gold, which is found at Vaulry, and traces of gold at St. Leonard, had probably been sought for by the old miners in these works.

(4) The silence of history, and the open character of the works, justify him in attributing them to the Gauls.

1407. PEARCE, GILBERT B. Blocks of tin found in Fowey Harbour.

Journ. Roy. Inst. Cornwall, Vol. 15, pt. 2, 1903, Truro, pp. 345-346.

Brief account of four blocks of tin, very rough castings. As they bore no mark or coinage stamp, the writer infers that they probably belong to a time previous to the institution of the coinage law.

1408. PLINIUS, CAIUS. Natural History.

Bohns Classical Library.

Trans. by John Bostock & H. T. Riley, 1887, London.

Book 4, chap. 30, Vol. 1, p. 352.

Timaeus, the historian said to mention that "white lead" is found on the island of Mictis 6 days' sail from Britannia.

Book 7, chap. 57, Vol. 2, p. 225.

Midacritus was the first who brought tin from the island called Cassiteris.

Book 34, chap. 47, Vol. 6, pp. 212-215.

Greeks brought "white lead" from Lusitania and Gallæcia.

P. 213. "White lead was held in estimation even in the days of the Trojan war, a fact that is attested by Homer, who calls it 'cassiteros.'"

1409. POLWHELE, R. The history of Cornwall.

Vols. 7, 1816, London.

Not available to the authors.

HISTORY (Continued)

1410. RAWLINSON, GEORGE. Phœnicia.

1898, New York and London, pp. 66-67, 69-70.

Gives an account of the planting of colonies in Andalusia, Spain; led there by riches of country, among which gold, silver, quicksilver, tin, lead, copper and iron are mentioned as occurring in the mountains in which the ancient Baetis and tributaries rise. They also planted colonies on the Scilly islands, attracted by mineral wealth, and from there they exported tin and lead to Greece and Asia.

1411. REYER, —. Tin, and its history.

Mg. Journ. Railw. Comm. Gaz., Vol. 49, 1879, London, p. 1299.

Historical sketch of tin beginning with 1800 B. C. down to 1873, A. D., when Tasmanian stream tin became known.

1412. REYER, EDUARD. Allgemeine Geschichte des Zinnes.

Oest. Zeitschr. Berg. Hütt. Vol. 28, 1880, Wien, pp. 499-501, 514-516.

Translated by Symons, B. in 1881. Trans. Mg. Ass. Inst. Cornwall, Vol. 4, 1893, pp. 138-150.

Review: Eng. Mg. Journ., Vol. 31, 1881, New York, pp. 313-314.

Digest: Ann. Brit. Geol. 1893, London, p. 280.

"The name 'tin' is of Gallic origin, being derived from 'ostean,' Cornish 'stean.' It is estimated that in 1881 the production of tin in the various parts of the world was: Australia, 10,000 to 15,000 tons; England, 10,000; Straits of Malacca, etc., 10,000; Banca and Billiton, 7000 to 9000; Tasmania, 3000 to 5000; and China, 5000 tons."

1413. RHYS, JOHN. Early Britain, Celtic Britain.

1904, London, pp. 44, 46, 48, 204, 287.

Gives account of early tin trade, history of Cassiterides, location, etc.

1414. SAUNDERS, C. D. The ancient Cornish tin trade.

33d Ann. Rep. Roy. Cornwall Polyt. Soc., 1865, Falmouth, pp. 42-45.

A discussion as to whether the Phœnicians carried on their tin trade as a maritime one, i. e. through the Pillars of Hercules, or as a land trade through Gaul to Mediterranean Sea.

SCHMIDT, ALBERT. *See* Nos. 570 and 571.

1415. SCHUURMAN, J. A. Historische schets van de tinwinning op Banka.

Jaarb. Mijnw. Ned. Oost-Indië, 1898, II, Tech. and Admin. Amsterdam, pp. 1-112.

1416. SIMONIN, L. Sur l'ancienne exploitation des mines d'étain de la Bretagne.

C. R. Acad. Sci., Vol. 62, 1866, Paris, pp. 346-347.

1417. SMIRKE, EDWARD. Tin trade between Britain and Alexandria in the 17th century.

Journ. Roy. Inst. Cornwall, Vol. 2, 1867, Truro, pp. 283-291.

1418. SMITH, GEORGE. The Cassiterides: an inquiry into the commercial operations of the Phœnicians in Western Europe, with particular reference to the British tin trade.

1863, London, pp. 154.

Believes that tin was obtained from Cornwall as early as the period between 1200 and 1500 B. C., and that tin did not come from Malay Peninsula during these early times.

1419. TAYLOR, JOHN. Sketch of the history of mining in Devon and Cornwall.

Philos. Mag. Vol. 5, 1800, London, pp. 357-365.

HISTORY (Continued)

1420. TYLOR, A. Is Iktis in Cornwall, and did iron and copper precede tin?

Mg. Journ. Railw. Comm. Gaz., Vol. 53, 1883, London, p. 1395, sketch maps 4.

Historical. States that pure iron was used in Egypt B. C. 3124, and argues that since iron was a necessity for production of copper, and tin was of no use without copper, iron and copper must have been known first.

WAIT, F. W. *See* No. 482.

1421. WARNER, RICHARD. A tour through Cornwall (with an account of the mines).

1809, Bath and London, pp. 245-282.

Gives a sketch of the early history of tin, and in a brief way, the geology of tin deposits of Cornwall.

WEEKS, JOSEPH D. *See* No. 1372.

1422. WERNER, —. Le plus ancien de tous les métaux.

Journ. Mines No. 18, Vol. 3, 1795 et 1796, Paris, pp. 90-96.

1423. WHEELER, H. A. Tin mining in the Ozarks. A bit of history.

Eng. Mg. Journ., Vol. 77, 1904, New York, p. 323.

Describes attempt to mine tin at Tin Mountain, some 10 miles south of Fredericktown, about 130 miles south of St. Louis, Mo., where there was no tin. Exposes the methods used. Account of a clever fraud.

1424. WINER, —. Die Metalle und Mineralien bie den alten Egyptiern.

Berg. Hütt. Zeit., Vol. 40, 1881, Leipzig, p. 467.

Tin is mentioned among the metals used by the ancient Egyptians.

1425. WORTH, R. N. Historical notes concerning the progress of mining skill in Devon and Cornwall.

40th Ann. Rep. Roy. Cornwall Polyt. Soc., 1872, Falmouth, pp. 63-121.

From a historical point of view the author treats of the discovery, methods and progress of early mining, including tools, machinery and power; dressing, smelting and sale of tin and copper, with short discussion of the early miner.

1426. ———. The antiquity of mining in the west of England.

42d Ann. Rep. Trans. Plymouth Inst. Devon and Cornwall Nat. Hist. Soc., 1873-1874 (1874), Plymouth, pp. 120-140.

Conclusions reached are:

"First. That the historical evidence of the antiquity of western mining takes it back at least 2300 years.

"Second. That the inferential evidence carries it nearly 2000 years further, and possibly doubles the first-named period.

"Third. That the geological evidence would antedate the commencement of mining, and consequently the use of metals, to a time when the mammoth either still existed in the west of England, or had not long disappeared; and when the general level of Devon and Cornwall was at least 30 feet higher than it is now. Taking Sir Charles Lyell's estimate of the rate of crust motion at 2½ feet in a century, fully 2000 years would thus be covered by the gradual process of subsidence and whilst we cannot tell when it ended, nor perhaps accurately estimate the chronological value of later changes, we know from St. Michael's Mount that it must have ceased certainly 2000 years ago; whilst other reasons appear to indicate a much more remote antiquity."

1427. ———. The ancient stannary of Ashburton.

Trans. Devonshire Ass. Adv. Sci. Lit. Art, Vol. 8, 1876, Plymouth, pp. 311-322.

Digest: Geol. Rec. for 1876, London, p. 332.

"An historical account of the stannaries of Devonshire with special reference to that of Ashburton, from the year 1197; statistics as to the produce of tin in county, and note of the minerals found."

IV. METALLURGY AND CHEMISTRY

1428. AARON, C. H. **Assaying of tin ores.**

Assaying, pts. II and III, 1900, San Francisco, pp. 127-128.

Short account of methods used in assaying tin ore.

AGRICOLA, GEORGIUS. *See* No. 1277.

1429. ALLARD, —. **Crystallization of tin.**

Ann. Indust. nat. étr., April, 1820, Paris.

Translated and abstracted by Editor Amer. Journ. Sci. Arts, 1st ser., Vol. 17, 1830, New Haven, pp. 206-208.

A method of producing "moiré métallique" on tin plate by the application of acids and heat.

1430. ALLEN, ALFRED H. **On metastannic acid and the detection and estimation of tin.**

Chem. News, Vol. 25, 1872, London, pp. 170-171.

Abstract of paper read before the Chemical Society, March 7, 1872.

Finds that matastannic acid is much more soluble in acids than had been supposed by Fresenius and others, and that ordinary stannic sulphate is formed by treatment with hot H_2SO_4. Uses this reaction in the estimation of tin in alloys.

1431. ALLEN, J. F. **On the alloys of tin, zinc, lead and other metals with manganese.**

Rep. Brit. Ass. Adv. Sci. 40th meeting, September, 1870, Liverpool, pt. 2, 1871, London, pp. 50-51. [Abs.]

Makes manganese-copper alloy from the oxides, then adds tin or other metal, forming an alloy that can be rolled or cast for bearings, etc.

1432. ANONYMOUS. **Improved method of estimating tin.**

Mg. Journ. Railw. Comm. Gaz., Vol. 20, 1850, London, p. 489.

"Hitherto in chemical analysis tin has always been estimated in the form of stannic acid (peroxide of tin) . . . . . The new method depends on the facility with which protochloride of tin withdraws chlorine from bodies capable of furnishing it."

1433. ———. **Properties of the alloys of copper and tin.**

Iron Age, Vol. 24, 1879, Dec. 4, New York, p. 15; Dec. 11, pp. 9, 11; Dec. 18, p. 8.

Gives results of torsional, compressive and transverse stress tests; analyses and specific gravities; and a comparion of the ductilities of various bronzes.

1434. ———. **Disintegration of tin.**

Mg. Sci. Press, Vol. 44, 1882, San Francisco, p. 275.

Short discussion of the cause of the disintegration of tin from cold. Theory advanced that it is due to crystallization, possibly to dimorphism.

1435. ———. **Recovering tin from scrap tin.**

Mg. Sci. Press, Vol. 49, 1884, San Francisco, p. 51.

Describes a process of tin recovery by oxidizing the tin on tin scrap in heated air. Copied. Original place of publication unknown to authors.

METALLURGY AND CHEMISTRY (Continued)

1436. ———. Mercurialized tin.

Eng. Mg. Journ., Vol. 45, 1888, New York, p. 217.

Note from "Chemical Journal," of Nüremberg stating persons working in a smelting establishment were poisoned by tin containing 1.3 per cent Hg.

1437. ———. Assais des minerais d'étain par la voie seche.

Métallurgie, Vol. 28, 1897, Paris, pp. 331-333.

1438. ———. Recovering tin from scrap.

Eng. Mg. Journ., Vol. 76, 1903, New York, p. 58, about 150 words.

Plants for the recovery of metallic tin are being operated in Germany [seven], Austria [one], England [one]. Germany is drawing supplies for tin recovery plants from England, France and Switzerland.

1439. ———. British patent, 736, 924 of 1903.

Eng. Mg. Journ., Vol. 76, 1903, New York, p. 360.

Electrolytic method of recovering tin from scrap.

1440. ———. Electrolytic production of tin.

Queensland Gov. Mg. Journ., November, 1904, Brisbane.

"Description of German patent for obtaining tin from any substance containing the metal."

Not available to the authors.

1441. ———. Electrolytic methods of treating tin scrap.

Engineer, Vol. 98, 1904, London, pp. 5-6, 2500 words.

Details of all processes which have been tried industrially; cost of operating, and the future of industry.

1442. ———. Recovery of tin from old cans.

Eng. Mg. Journ., Vol. 79, 1905, New York, p. 428, 500 words.

"Tin cans are put in 2 per cent solution of $SnCl_4$, which dissolves tin forming SnCl. Then electrolysed, tin falling in crystals .1875 in. long and solution again containing $SnCl_2$ is pumped back. Carried on at 70° F. Known as Bergse process and used at Copenhagen, Denmark, works.

1442a. ———. Wet method for the assay of tin in ores, etc.

South African Mg. Journ., May 2, 1908, Johannesburg, p. ¾.

"Gives a simple and reliable process for the determination of tin in tin ores by the wet method."

1442b. ———. Detinning industry.

Iron and Coal Tr. Rev., Vol. 78, 1909, London, p. 415, fig. 2.

"A review of the detinning industry with notes on chlorine detinning and also a short note on the Goldschmidt company."

———. *See* No. 1294.

1443. Balling, Carl. Manuel pratique l'art de l'assayeur.

1881, Paris, pp. 488-500.

Methods of assaying tin ores.

1444. Bannister, C. O. On the assay of auriferous tinstone.

Trans. Inst. Mg. Met., Vol. 15, 1905-1906, London, pp. 513-519. Discussion pp. 520-523.

Gives results obtained in assaying stream-tin for gold by scorification, crucible assay, a wet method, concentration of the gold in a part of the tin, and by the collection of the gold in the whole of the tin. Considers the crucible method to be the best.

METALLURGY AND CHEMISTRY (Continued)

1445. Béchamp, A., and Saintpierre, C. Recherches sur la séparation [par voie humide] de l'or et du platine, d'avec l'étain et l'antimoine.
C. R. Acad. Sci., Vol. 52, 1861, Paris, pp. 757-759.

1446. Bergemann, C. Mineral-Analysen. Zinnstein von Xeres in Mexico.
Neues Jahrb. Min., 1857, Stuttgart, p. 395.

1447. Berglund, Emil. Neue Methode zur qualitativen Scheidung von Zinn, Antimon und Arsen.
Berichte deutsche Chemische Gesellschaft, Vol. 17, I, 1884, Berlin, pp. 95-98.
Digest: Amer. Chem. Journ., Vol. 7, 1885-1886 (1886), Baltimore, p. 133.

1447a. Beringer, J. J. Wet assay of tin ores.
Mg. Mag., Vol. 1, 1909, London, pp. 231-232.
Discussion by Pearce, Richard, ibid., pp. 307-308.

1448. Berthelot, —. Action de l'oxygène sur les chlorures acides et composés analogues: étain, silicium, bore.
C. R. Acad. Sci., Vol. 86, 1878, Paris, pp. 920-926.

1449. Berthier, P. Analyse d'un étain allié.
Ann. Mines, 3d ser., Vol. 11, 1837, Paris, pp. 513-514.

1450. ———. Analyse d'un étain allié. [Extrait.]
Ann. Mines, 3d ser., Vol. 19, 1841, Paris, pp. 702-703.

1450a. Bettel, W. Assaying tin ores.
South African Mg. Journ., September 12, 1908, Johannesburg, pp. 1½.
"Discusses the various methods for the assay of tin and compares the merits of the Cornish wet and dry methods."

1451. Betts, Anson G. Electrolytic lead refining. [Tin in refined lead.]
Trans. Amer. Inst. Mg. Eng., Vol. 34, 1903, New York, p. 180.
Tin has been found in electrolytically refined lead at Trail, B. C., to the extent of 0.02 per cent. No difficulty is experienced in removing this from the lead by poling before casting.

1452. Billings, G. H. The properties of iron alloyed with other metals.
Trans. Amer. Inst. Mg. Eng., Vol. 5, 1877, New York, p. 450.
Reprint: Eng. Mg. Journ., Vol. 23, 1877, New York, pp. 394-395.
Results of experiments made by combining a small per cent of tin with iron. Of all metals alloyed with iron, experiments point to the fact that tin has the most hurtful effect.

1453. Bohne, E. Vererbeitung der Schlacken vom Zinnerzschmelzen vermittelst verdünnter Schwefelsäure.
Berg. Hütt. Zeit., Vol. 57, 1898, Leipzig, pp. 203-204.
Digest: Proc. Inst. Civ. Eng., Vol. 133, 1898, London, pp. 452-453.
"The final slags produced in smelting of tin ores in the reverberatory furnace cannot, as a rule, be brought to lower content of tin than about 4 per cent, which in works smelting ten tons of ore daily, represents a loss of 3 cwt. to 4 cwt. of metallic tin. Author finds that this may be recovered to a great extent by decomposing the slag with sulphuric acid, when the iron and tin are dissolved, giving a solution from which the latter metal may be recovered by electrolysis."

1454. Boucard, A. Dosage de l'étain dans les minerais.
Rev. Univ. Mines Mét. Trav. Publ. Sci. Arts Appl. Indust., sem. 2, Vol. 8, 1860, Liége and Paris, pp. 482-483.

METALLURGY AND CHEMISTRY (Continued)

1455. ———. Recherches sur la séparation par voie humide de l'or et du platine d'avec l'étain et l'antimoine.

Rev. Univ. Mines Mét. Trav. Publ. Sci. Arts Appl. Indust., sem. 2, Vol. 10, 1861, pp. 171-173.

1455a. BRACKENBURY, C. Notes on tin dressing.

Bull. Inst. Mg. Met., 52, Jan. 14, 1909, London.

"Contributed remarks in which the author gives a series of experiments showing a great variation between vanning assays and chemical assays of tin ore."

1456. BRANDENBURG, H., WEYLAND, A., and KEMPEN, A. R. British patent, 16,377 of 1903.

Eng. Mg. Journ., Vol. 76, 1903, New York, p. 630.

"Tin extraction from dross. The use of a mixture of sulphuric and hydrochloric acids for extracting tin from dross and slags, the whole of the tin being thus extracted in soluble form without being thrown down as oxide."

1457. BROOKS, CECIL J. Quantitative estimation of tin.

Eng. Mg. Journ., Vol. 61, 1896, New York, p. 494.

A brief record of experiments made to ascertain the cause of the low results which are often obtained in the determination of tin.

1458. BROWNE, FRANK. Chinese tin.

Chem. News, Vol. 95, 1907, London, pp. 3, 4.

Abstract by W. S. Landis in Chem. Abs., No. 5, Vol. 1, March 5, 1907, Easton, p. 549.

Description of a Chinese method of smelting tin.

1459. BUNSEN, R. Unterscheidung und Trennung des Arseniks von Antimon und Zinn.

Ann. Chem. Pharm., Vol. 106, 1858, Heidelberg, p. 3.

1460. CAHOURS, A. Recherches sur les radicaux organo-métallique.

C. R. Acad. Sci., Vol. 48, 1850, Paris, pp. 833-837.

Action des alliages d'étain et de sodium sur les éthers iodhydriques des différentes séries alcooliques.

1461. CAHOURS, A., and DEMARÇAY, E. Sur les stannpropyles et les isostannpropyles.

C. R. Acad. Sci., Vol. 88, 1879, Paris, pp. 1112-1117.

1462. ———. Sur les radicaux organométalliques de l'étain. Stannbutyles et stannamyles.

C. R. Acad. Sci., Vol. 89, 1879, Paris, pp. 68-73.

1463. CAHOURS, A., and RICHE, A. Recherches sur le stannéthyle, nouveau radical organique renfermant de l'étain.

C. R. Acad. Sci., Vol. 35, 1852, Paris, pp. 91-95.

Abstract in Amer. Journ. Sci. Arts, 2d ser., Vol. 14, 1852, New Haven, p. 421.

Description of and mode of making an organic tin compound to whose radical the authors give the name "stannethyl."

1464. ———. Recherches sur un nouveau radical organique refermant de l'étain, le stanméthyle.

C. R. Acad. Sci., Vol. 36, 1853, Paris, pp. 1001-1004.

METALLURGY AND CHEMISTRY (Continued)

1465. CAPITAINE, H. De l'action de l'étain, de l'arsenic, de l'antimoine et du soufre sur les chlorures de mercure.

Ann. Mines, ser. 3, Vol. 17, 1840, Paris, pp. 441-445.
Extrait: Journ. Pharm., Vol. 25, 1839, Paris, p. 50.

1466. CARPENTER, F. R., and HEADDEN, W. P. Note on the influence of columbite upon the tin assay.

Trans. Amer. Inst. Mg. Eng., Vol. 17, 1889, New York, pp. 633-636.
Discussion by Blake, W. P., ibid., pp. 785-787.
The results of assays made upon tin ores from the Black Hills are given: conclude that the presence of columbite is injurious, and that the buttons owe their increase in weight to impurities derived from it.

CHARLETON, ARTHUR G. *See* No. 1310.

CLARK, DONALD. *See* No. 1076.

1467. CLARKE, F. W. On a new method of separating tin from arsenic, antimony and molybdenum.

Chem. News, Vol. 21, 1870, London, p. 124.
Amer. Journ. Sci. Arts, ser. 2, Vol. 49, 1870, New Haven, pp. 48-51.
Reviewed by Koninck, L. L. de.—Rev. Univ. Mines, Mét. Trav. Publ. Sci. Arts Appl. Indust., ser. 1, Vol. 29, 1871, Liége and Paris, p. 151.
(See No. 1477.)

1468. COLLINS, HENRY F. On adobe and other cheap and makeshift furnaces.

Trans. Inst. Mg. Met., Vol. 12, 1902-1903, London, p. 425.
Reference to furnaces and slags at some large old tin mines at Bundi, Federated Malay States.

1469. COLLINS, J. H. On the assay of tin and on the solubility of cassiterite.

Trans. Inst. Mg. Met., Vol. 13, 1905, London, pp. 485-486, remarks, p. 487.
Reprint: Austr. Mg. Stand., Vol. 32, 1904, Sydney and Melbourne, p. 174.
Abstract: Eng. Mg. Journ., Vol. 77, 1904, New York, p. 928.
Believes vanning to be the best mine test, and reduction by fusion of SnO_2 with KCN a good assay. Finds that finely powdered SnO_2 may be largely dissolved by H_2SO_4 and zinc, and with HCl.

1470. ———. The use of the impact screen in tin dressing.

Mg. Mag., June, 1906, New York, p. 521.
Abstract: Journ. Chem. Met. Min. Soc. South Africa, Vol. 7, 1906, Johannesburg, pp. 54-55.

1471. COWPER, COLES S. Electrolytic refining of tin and treatment of tin ores.

Electr. Eng., Vol. 22, 1898, New York, pp. 81-82.
Digest: Min. Proc. Inst. Civ. Eng., Vol. 136, pt. II, 1898-1899 (1899), London, p. 442.
Description of various methods tried from time to time for the electrolytic refining of tin, and also for the recovery of tin from its ores. The process of Claus, which consists in using an electrolyte of stannate of sodium or sulpho-stannate of sodium, is given as one of the most successful methods.

1472. CRAMER, JOHN ANDREW. Elements of the art of assaying metals. Translated from the Latin. Illustrated with copper plates.

1741, London.
The titles of the chapters dealing with tin are:
1. Tin, pp. 3, 19-20.

METALLURGY AND CHEMISTRY (Continued)

2. Precipitation of silver out of tin, by scorification, pp. 228-230.
3. The reduction of tin ore in a close vessel, pp. 324-335.
4. The reduction of tin ore, extempore, pp. 335-336.
5. To reduce tin ore by a stratification with coals, pp. 336-337.

1473. CROOCKEWIT, J. H. Over de wijze van uitsmelting (herleiding) van den tinerts door de Chineezen op Banka.

1852, Batavia, pp. 37.
Not available to the authors.

1474. DE KONINCH, L. L., and LECRENIER, A. Séparation qualitative de l'or et du platine d'avec l'arsenic, l'antimonie et l'étain.

Rev. Univ. Mines Mét. Trav. Publ. Sci. Arts Appl. Indust., ser. 3, Vol. 2, 1888, Liége and Paris, pp. 98-99.

1475. DELACHANAL, B., and MERMET, A. Sur un composé de platine, d'étain et d'oxygène, analogue au pourpre de Cassius.

C. R. Acad. Sci., Vol. 81, 1875, Paris, pp. 370-371.

1476. DELVAUX DE FENFFE, A. Purification de l'étain et emploi du tungstène pour l'amélioration de l'acier et de la fonte de fer.

Rev. Univ. Mines Mét. Trav. Publ. Sci. Arts Appl. Indust., sem. 1, Vol. 7, 1880, Liége and Paris, pp. 81-86.

1477. DEWEY, FRED P. On Clarke's method for the separation of tin from arsenic and antimony.

Amer. Chem. Journ., Vol. 1, 1879-1880 (1880), Baltimore, pp. 244-251.
See No. 1467.

1478. DIEST, P. H. VAN. Het tinsmelten op Bangka.

Jaarb. Mijnw. Ned. Oost-Indië, 1872, I, Amsterdam, pp. 217-253. Twee platen en twee bijlagen.

Abstract: Berg. Hütt. Zeit., Vol. 32, 1873, Leipzig, pp. 423-424.

Bijlage I, Bevattende het rapport der Commissie tot het uitvoeren van vergelijkende smeltproeven, ingesteld bij gouvernementsbesluit, dd. 2 Mei 1866.

Bijlage II, Beschrijving van de inrichting, den bouw en het gebruik van den nieuwen of vierkanten smeltoven voor Bangka.

1479. DIETZSCH, F. The treatment of tin-wolfram-copper ores at the Clitters United Mines.

Trans. Inst. Mg. Met., Vol. 15, 1906, London, pp. 2-28, discussion, pp. 29-61, figs. 5.

A detailed account of new methods used in reopening and working the old Clitters mine, near Gunnislake in East Cornwall.

1480. DIJK, P. VAN. Omsmelting en zuivering van drie partijen Banka-tin aan het Koloniaal Etablissement te Amsterdam.

Jaarb. Mijnw. Ned. Oost-Indië, 1890, Amsterdam, I, Tech. en Admin. pp. III-XXIII, Verslag, waarbij twee platen.

1481. DOUGLAS, J. C. The cry of tin.

Mg. Sci. Press, Vol. 43, 1881, San Francisco, p. 99.

The sound emitted by tin when bent, is not peculiar to tin and can be imitated with other metals of a crystalline structure. Heated rolled zinc emits a "cry" like tin, only fainter. Cast zinc, if pinched between the teeth or plier emits the sound distinctly. This cry, alone or in conjunction with a microphone, becomes an indicator of the crystalline texture of metal beams and their fitness for certain classes of work.

The original place of publication is unknown to the authors.

METALLURGY AND CHEMISTRY (Continued)

1482. DUSSAUCE, —. Metallurgy of tin.

Amer. Journ. Mg. Mill. Oilb. Geol. Min. Met., Vol. 4, 1867, New York, pp. 354-355, 371, 386-387.

Describes the ores of tin, localities where found, preparations for smelting, and smelting and refining processes. Serial. First three articles only available to the authors.

1483. DYKES, F. J. B. Analysing of tin slag.

Perak Gov. Gaz., Vol. 17, No. 26, July 15, 1904, Supplement, Kuala Lumpur, Malay Peninsula, p. 1.

Ten analyses of slags from slag heaps at native furnaces gave from 2.32 per cent to 8.4 per cent tin.

1483a. EDWARDS, C. P. Assay of tin.

South African Mg. Journ., November 7, 1903, Johannesburg, p. ¾.

"A description of the method used, with special reference to adapting the scheme to different ores."

1484. EGLESTON, T. The law of fatigue and refreshment of metals. Effect of vibration on tin.

Trans. Amer. Mg. Eng., Vol. 8, 1879-1880, New York, pp. 400-401.

Tin is apparently an exceptional metal in its behavior under vibration, although enough data could not be obtained to prove the law or the exception.

ELLIS, THOS. F., and MCKILLOP, JOHN. *See* No. 1530.

1485. ELSNER, L. Moyen de séparer l'arsenic de l'étain.

Ann. Mines, ser. 3, Vol. 19, 1841, Paris, p. 529.

Extract from Ann. Chem. Pharm., Vol. 32, Heidelberg.

1486. ———. Ueber die Trennung des Goldes und Platins von Zinn und Arsenik.

Journ. prakt. Chem., Vol. 35, 1845, Leipzig, pp. 310-312.

1487. ENGEL, R. Sur les acides stanniques.

C. R. Acad. Sci., Vol. 125, 1897, Paris, pp. 651-654.

1488. ———. Sur l'action de l'étain azotique sur l'étain.

C. R. Acad. Sci., Vol. 125, 1897, Paris, pp. 709-711.

FLOWER, P. W. *See* No. 1390.

1489. FLOWER-ELLIS, T. J. A brief account of the Malay tin industry.

Proc. Chem. Met. Soc. South Africa, Vol. 2, 1897, Johannesburg, pp. 5-18, fig. 1.

Reprint: Mg. Journ. Railw. Comm. Gaz., Vol. 67, 1897, London, pp. 532, 592-593.

Peninsula is described as a "huge ridge of granite and porphyry, with occasional tracts of overlying and highly distorted sandstone, slate, schists and limestones, the lower ground being filled in with alluvial beds of clay, sand and gravel." Ore is associated with granite, both in lode and alluvial deposits. Richest pay gravel rests on the lowest clay bed, usually an impure kaolin. Methods of obtaining valuation of tin-bearing ground, Chinese method of mining, methods of smelting used by both Chinese and Europeans, tests for quantity of tin given.

1490. FOULLON, H. VON. Ueber Krystallisirtes Zinn.

Jahrb. k. k. geol. Reichs., Vol. 34, 1884, Wien, pp. 367-384, mit 2 Holzschn. u. 1 Taf.

Review: Neues Jahrb. Min., 1885, II (Ref.), Stuttgart, pp. 266-268.

METALLURGY AND CHEMISTRY (Continued)

1491. FRANCKEN, V. Determination de l'étain.

Rev. Univ. Mines Mét. Trav. Publ. Sci. Arts Appl. Indust., ser. 2, Vol. 11, 1882, Liége and Paris, p. 503.

1492. FRITZCHE, P. Sur un phénomène de rupture produit au milieu de blocs d'étain sous l'action d'un froid intense.

C. R. Acad. Sci., Vol. 67, 1868, Paris, pp. 1106-1107.

1493. FRAENKEL, A., and FASAL, J. Estimation of tin in salts of tin.

Chem. News, Vol. 78, 1898, London, pp. 100-101.

Mitth. k. k. Techn. Gewerbe-Museums in Wien, Vol. 7, 1907, Wien, p. 227.

Extract: Rev. Univ. Mines Mét. Trav. Publ. Sci. Arts Appl. Indust., ser. 3, Vol. 44, 1898, Liége and Paris, pp. 301-302.

Digest: Eng. Mr. Journ., Vol. 66, 1898, New York, p. 333.

"The authors have worked out a method for the estimation of tin which consists in precipitating this metal on aluminum dissolving the two metals in hydrochloric acid, and titrating the stannous chloride thus formed by means of iodine or bichromate of potassium."

1494. GAULTIER DE CLAUBRY, H. F. Dosage de l'étain par volumes.

C. R. Acad. Sci., Vol. 22, 1846, Paris, pp. 861-862; Vol. 23, 1846, pp. 101-103.

Extrait par l'auteur.

1495. GAY-LUSSAC, LOUIS J. Sur la séparation de l'antimoine d'avec l'étain.

Ann. Chim. Phys., Vol. 46, 1831, Paris, p. 222.

Ann. Physik. Chem., Vol. 21, 1831, Leipzig, pp. 589-590.

Extrait: Ann. Mines, ser. 3, Vol. 2, 1832, Paris, pp. 329-330.

Extract: Amer. Journ. Sci. Arts, ser. 1, Vol. 27, 1835, New Haven, p. 197.

1496. GERARDIN, A. (?). Note sur le bichlorure d'étain considéré comme un dissolvant.

C. R. Acad. Sci., Vol. 51, 1860, Paris, p. 1097.

1497. GMEHLING, ANDREAS. Metallurgische Beiträge aus Bolivia.

Oest. Zeitschr. Berg. Hütt., Vol. 38, 1890, Wien, pp. 269-273, 281-286, 294-295, pls. 13, 14.

1497a. GOLDSCHMIDT, K. Recovery of tin from tin-plate waste.

Oest. Zeitschr. Berg. Hütt., 1909, Wien, p. 103.

Digest translation in Min. Proc. Inst. Civ. Eng., Vol. 177, pt. 3, 1909, London, pp. 358-359.

Describes the removal of tin from tin scrap, including tin cans, by the dry chlorine process.

Estimates 75,000 tons of scrap are treated in Germany each year, and about 25,000 tons in the rest of Europe, making 1500 tons of tin and tin-salts. In America 60,000 tons, giving 3000 to 3500 tons tin or 3½ per cent of the world's product.

Goldschmidt handles 50,000 tons in Germany.

1498. GREGOR, W. Observations on a remarkable change which metallic tin undergoes, under peculiar circumstances, and on its partial conversion into a muriate of tin.

Trans. Roy. Geol. Soc. Cornwall, Vol. 1, 1818, Penzance, pp. 51-59.

Description of metallic tin changed to chloride of tin, presumably through weathering in air near the sea.

HALSE, ED. *See* No. 773.

METALLURGY AND CHEMISTRY (Continued)

1499. HAÜY, —. Substances Métalliques.
Journ. Mines, Vol. 5, No. 30, 1796, Paris, pp. 457-466.

1500. HAWKINS, JOHN. On a process of refining tin.
Trans. Roy. Geol. Soc. Cornwall, Vol. 1, 1818, Penzance, pp. 201-211.
A proposal to purify tin by allowing impurities to settle from liquid mass.

1501. HAYES, AUGUSTUS A. On the action of metallic tin on solutions of muriate of tin.
Amer. Journ. Sci. Arts, ser. 1, Vol. 38, 1840, New Haven, pp. 408-410.

1502. HEADDEN, WM. P. Formation of the alloys of tin and iron with description of some new alloys.
Proc. Colorado Sci. Soc., Vol. 4, 1891, Denver, pp. 81-122.
Abstract: Amer. Journ. Sci. Arts, ser. 2, Vol. 44, 1892, New Haven, pp. 464-468.

1503. HENZ, F. Beitrag zur Kenntniss Trennung von Antimon und Zinn mittels Oxalsäure.
Zeitschr. Anorg. Chem., Vol. 37, 1903, München and Leipzig, pp. 39-58.
Based upon Dr. Clarke's article, No. 1467.

1504. HEYCOCK, C. T., and NEVILLE, F. H. On the constitution of copper-tin alloys.
Proc. Roy. Soc. London, Vol. 69, 1902, London, pp. 320-329.
Conclusions reached from a number of experiments on alloys of tin and copper.

1505. HICKS, JAMES. Treatment of slime tin.
Trans. Mg. Ass. Inst. Cornwall, Vol. 4, 1893-1895, Camborne, pp. 111-137, illus. 4.
Read at Camborne, December 20, 1892.
Short review: Mg. Sci. Press, Vol. 66, 1893, San Francisco, p. 244.
Showing waste of mines under management at that time and ways of saving slime tin ore.

1505a. HIORTDAHL, F. H. Sur la forme cristalline des combinaisons des stannméthyles et leurs homologues.
C. R. Acad. Sci., Vol. 88, 1879, Paris, pp. 584-586.

1506. HOFMAN, HEINRICH O. The dry assay of tin ores.
Trans. Amer. Inst. Mg. Eng., Vol. 18, 1889-1890, New York, pp. 3-54.
Also, Techn. Quart., Vol. 3, 1890, Boston, pp. 112-143, 261-280.
Describes a series of experiments with the tin ores of the Black Hills to ascertain the best method of assay.

1506a. HOHAGEN, GEORG. Assay of tin ores.
Eng. Mg. Journ., Vol. 85, 1908, New York, p. 422.
Short article on methods used in assaying tin ores.

1507. HUGHES, T. W. H. Notes on tin smelting in the Malay Peninsula.
Rec. Geol. Surv. India, Vol. 22, pt. 4, 1889, Calcutta, pp. 235-236.
Notes on the use of the native or Tonka type of furnace, and more especially upon the English furnace at Singapore.

1507a. HUTCHIN, H. W. Notes on tin dressing.
Trans. Inst. Mg. Met., Vol. 18, 1908-1909, London, pp. 69-107.
Review: Eng. Mg. Journ., Vol. 87, 1909, New York, pp. 651-652.
Describes a series of investigations on tin ore dressing performed at South Crofty mine, Cornwall. The work covers in particular the preparation of concentrates for the calciner.
The paper is discussed by various members and author's reply given.

METALLURGY AND CHEMISTRY (Continued)

1507b. ———. Tin dressing.
Mg. Mag., Vol. 2, 1910, New York, pp. 295-296.

1508. JOLYET, F., and CAHOURS, A. Recherches sur l'action physiologique des stannéthyles et des stanméthyles.
C. R. Acad. Sci., Vol. 68, 1869, Paris, pp. 1276-1280.

1509. KENNGOTT, A. Ueber die alkalische Reaction einiger Minerale.
Neues Jahrb. Min., 1867, Stuttgart, pp. 437-438.

1510. KERL, BRUNO. The Assayer's Manual. An abridged treatise on the docimastic examination of ores, and furnace and other artificial products.
Translated from the German by W. T. Brannt, 1883, London, pp. 214-224.
Treats of the determination of tinstone by washing; and by both fire and wet assays.

1511. KERSHAW, JOHN B. C. Progress in electrochemistry and electrometallurgy in 1902.
Min. Ind. for 1902, Vol. 11, 1903, New York and London, p. 235, 300 words.
The electrolytic method of stripping tin from tin scrap and waste appears to be extending. The consumption of tin scrap in Germany alone is said to reach 30,000 tons per annum.

1511a. ———. Electro-Metallurgy.
D. Van Nostrand Co., 1908, New York, pp. 256-268.
Treats of the electric separation of tin from tin scrap.

1512. KERSTEN, C. M. Ueber die chemische Zusammensetzung mehrerer Sorten ungereinigten, so wie gereinigten Abgangszinnes von Altenberg und zweier Zinnsorten aus Peru.
Arch. Min. geogn. Bergb. Hütt., Vol. 22, 1848, Breslau and Berlin, pp. 662-690.

1513. KLAPROTH, MARTIN H. Analytical essays toward promoting chemical knowledge of mineral substances.
[Translated from German.] 1801, London, pp. 515-531.
1. Chemical examination of the native oxyd of tin.
a. Experiments in a dry way.
I. Assays in charcoal-crucibles.
II. Habitudes of tinstone, when exposed to heat in a crucible made of clay.
b. Experiments in a humid way.
2. Chemical examination of the native sulphuret of tin.
Samples of tin ore from Cornwall and Germany were used in these analyses.

1514. KÜNZEL, C. Ueber die Verarbeitung von Weissblechabfällen.
Berg. Hütt. Zeit., Vol. 33, 1874, Leipzig, pp. 57-60.

1515. LAMPADIUS, W. A. De l'essai et de l'analyse des minerais d'étain.
Ann. Mines, Vol. 3, 1818, Paris, pp. 203-208.

1516. ———. Versuche mit einem Quarzzuschlage bei dem Verschmelzen der Zinnerze zu Altenberg.
Arch. Bergb. Hütt., Vol. 14, 1827, Breslau and Berlin, pp. 296-298.

1517. LATTA, GEO. J. The smelting of tin ore at the Mount Bischoff tin smelting works, Launceston.
Rep. Secr. Mines for 1899-1900, Tasmania, 1900, Hobart, pp. 91-92.
Gives the amount and kind of tin ores smelted during first half of 1899, the method of smelting used, proper mixtures of ores, and charges.

METALLURGY AND CHEMISTRY (Continued)

1518. Le Grice, C. V. Notice of an ancient smelting place for tin, generally called a Jew's House, lately discovered on the estate of Trereife, near Penzance.

Trans. Roy. Geol. Soc. Cornwall, Vol. 6, 1846, Penzance, pp. 43-46.

Early mode of smelting tin by filling a small excavation with sticks piled cross-wise, filling interstices with SnO_2 and setting afire. Called "Jews' House" because Jews first worked tin in England. Tin smelted in blast furnaces until early in 19th century.

1519. Levol, A. Méthod de séparation quantitative de l'étain d'avec l'antimoine.

Ann. Chem. Phys., ser. 3, Vol. 13, 1845, Paris, pp. 125-127.
Extracts: Ann. Mines, ser. 4, Vol. 8, 1845, Paris, pp. 200-201.
Amer. Journ. Sci. Arts, ser. 2, Vol. 1, 1846, New Haven, p. 107.
Journ. prakt. Chem., Vol. 35, 1845, Leipzig, p. 179.
Reviewed by Elsner, L., in Journ. prakt. Chem., Vol. 35, 1845, Leipzig, pp. 313-314.

1520. ———. De l'essai du minérai d'étain.

Ann. Chim. Phys., ser. 3, Vol. 49, 1857, Paris, pp. 87-91.

1521. ———. Note sur la sonorité de l'étain.

Ann. Chim. Phys., ser. 3, Vol. 56, 1859, Paris, pp. 110-111.

1521a. Levy, D. M., and Ewen, D. Waste products of smelting—The Bessemerising of hardhead.

Bull. Inst. Mg. Met., May 13, 1909, pp. 9.

Gives results of a research to determine, (1) whether a bessemerizing process lends itself to the profitable recovery of values from hardhead and other tin smelting products, and (2) the rate of oxidation and elimination of the constituents of hardhead.

1522. Lewy, B. Sur quelques combinaisons nouvelles du perchlorure d'étain.

C. R. Acad. Sci., Vol. 21, 1845, Paris, pp. 369-374.

1523. Louis, Henry. The metallurgy of tin.

Min. Ind. for 1896, Vol. 5, 1897, New York and London, pp. 533-588, figs. 30.
Review: Berg. Hütt. Zeit., Vol. 56, 1897, Leipzig, pp. 449-453.

1. Smelting in the shaft furnace: (a) old Cornish process; (b) the German process; (c) Chinese method of tin smelting; (d) treatment of the slag.
2. Tin smelting in the reverberatory furnace.

1524. ———. Notes on the metallurgy of tin during 1897.

Min. Ind. for 1897, Vol. 6, 1898, New York and London, p. 648.

1525. ———. Tin smelting at the Mt. Bischoff works, Launceston, Tasmania.

Min. Ind. for 1897, Vol. 6, 1898, New York and London, pp. 649-650.
Reprint: Berg. Hütt. Zeit., Vol. 58, 1899, Leipzig, pp. 174-175.
Short article giving plan of tin smelting furnace.

1526. ———. Notes on the metallurgy of tin.

Min. Ind. for 1898, Vol. 7, 1899, New York and London, pp. 716-717, fig. 1.

1527. ———. Notes on the metallurgy of tin.

Min. Ind. for 1899, Vol. 8, 1900, New York and London, pp. 629-631.
Gives a review of the progress of the metallurgy of tin during 1899.

1528. Löwig, —. New organic radicals, containing tin.

Journ. prakt. Chem., Vol. 57, Leipzig, p. 385.
Extract: Amer. Journ. Sci. Arts, ser. 2, Vol. 16, 1853, New Haven, pp. 116-118.
"Löwig has communicated the results of an elaborate investigation of the products resulting from the action of iodide of ethyl upon alloys of tin and sodium."

METALLURGY AND CHEMISTRY (Continued)

1529. MACKENZIE, GEO. L. Determination of tin in tailings and slimes.
Trans. Inst. Mg. Met., Vol. 13, 1903-1904, London, pp. 87-92, discussion and remarks, pp. 92-101, fig. 1.
Abstract: Eng. Mg. Journ., Vol. 77, 1904, New York, pp. 928-929.
Discusses: Cleaning the ore; reduction of stannic oxide to tin; solution of the reduced tin: (a) precipitation as stannic sulphide, (b) conversion of the stannic sulphide to oxide.

1530. MCKILLOP, JOHN, and ELLIS, THOS. F. Tin smelting at Pulo Brani, Singapore.
Proc. Inst. Civ. Eng., Vol. 125, pt. 3, 1896, London, pp. 145-162, discussion, pp. 163-174, correspondence, pp. 174-181, figs. 8.
Review: Mg. Sci. Press, Vol. 72, 1896, San Francisco, p. 484.
Review: Berg. Hütt. Zeit., Vol. 57, 1898, Leipzig, p. 164.
Treated under headings: General arrangement of the works; buying and handling ores; preparation of impure ores; system of labor in mixing charges; smelting furnaces; metallurgical processes; marketable tin; loss of tin; consumption of iron; consumption of culm; consumption of fuel; future improvements.

1531. MALLETT, J. W. Analysis of tin pyrites.
Amer. Journ. Sci. Arts, ser. 2, Vol. 17, 1854, New Haven, pp. 33-35.

1531a. MEADE, RICHARD K. The valuation of engineering alloys.
Chem. Engr., Vol. 7, 1908, pp. 235-243, Vol. 8, 1908, Chicago, pp. 45-50, 110-115.
Treats of the composition and uses and methods of analysis of the babbitt metal alloys.

1532. MÈNE, CH. Mémoire sur un nouveau mode de dosage de l'étain.
C. R. Acad. Sci., Vol. 31, 1850, Paris, pp. 82-84.
Extrait: Ann. Mines, ser. 4, Vol. 19, 1851, Paris, pp. 399-400.
Brief digest: Berg. Hütt. Zeit., Vol. 10, 1851, Leipzig, p. 256.

1533. MENGIN, U. Séparation et dosage de l'étain et de l'antimoine dans un alliage.
C. R. Acad. Sci., Vol. 119, 1894, Paris, pp. 224-226.

1534. MENNICHE, H. British patent, 17,616 of 1902.
Eng. Mg. Journ., Vol. 76, 1903, New York, p. 284.
"Tin ore treatment. A process for recovering silver, lead, bismuth, tungsten and copper from tin ores by roasting, grinding, moistening with water and then immersing in a bath of molten sodium bisulphate, all the metals but tin being transformed into sulphates, which can be removed."

1535. MILLEN, J. D. Tin smelting at Launceston, Tasmania.
Eng. Mg. Journ., Vol. 82, 1906, New York, p. 1135.
Abstract from the annual report of the Zeehan School of Mines and Metallurgy. Method of smelting Mt. Bischoff tin.

1536. MOISSENET, L. Du dosage de l'étain dans les minerals de ce métal.
C. R. Acad. Sci., Vol. 51, 1860, Paris, pp. 205-207. Extrait par l'auteur.

1537. MOODY, S. E. Hydrolysis of salts of iron, chromium, tin, cobalt, nickel and zinc in the presence of iodides and iodates.
Amer. Journ. Sci. ser. 4, Vol. 22, 1906, New Haven, pp. 178-180.

METALLURGY AND CHEMISTRY (Continued)

1538. MULDER [—]. Ueber das Banka-Zinn.
Chem. Gaz., 1849, London, No. 165.
Twenty specimens, mostly from different tin mines in Banka were examined, and found to contain only a trace of foreign metals.
One analysis was:

Iron	0.019	Copper	0.006
Lead	0.014	Pure tin	99.961

1539. MULLER, J. A. The analysis of tin ores.
Chem. News, Vol. 85, 1902, London, pp. 147-148.

1540. MUSCULUS, F. Des hydrates stanniques.
C. R. Acad. Sci., Vol. 65, 1867, Paris, pp. 961-963.

1541. MYRICK, C. M. Tin concentration in Cornwall.
Mg. Sci. Press, Vol. 86, 1903, San Francisco, p. 167, illus. 2.
Methods of tin concentration, improvements and results.

NEVIUS, J. NELSON. *See* No. 781.

1542. NORTH, OLIVER. The practical assayer.
1874, London.
Assay of tin, pp. 106-116.

1543. ORDWAY, JOHN M. On some soluble basic salts of tin.
Amer. Journ. Sci. Arts, ser. 2, Vol. 23, 1857, New Haven, pp. 220-223.

1544. OVERMAN, FREDERICK. Practical mineralogy, assaying and mining.
1882, Philadelphia.
Description of tin, pp. 68-69. Assay of tin ore, pp. 169-171.

1545. PARRY, L. Assay of tin and antimony.
1906, London, pp. 3-49, 2d Ed.
Describes various methods of tin assaying.

1545a. ———. Note on the eutectic alloy of lead and tin.
Mg. Journ. Railw. Comm. Gaz., Vol. 87, 1909, London, pp. 420-421.

1545b. ———. The assay of tin ore.
Mg. Journ. Railw. Comm. Gaz., Vol. 86, 1909, London, pp. 421-424.
Copied: Mg. Sci., Vol. 60, 1909, Denver, pp. 370-373.

1546. PEARCE, RICHARD. On the application of chemistry to the dressing of tin ores.
Mech. Mag., Vol. 6, n. s., 1861, London, p. 339.

1547. ———. Description of the process for the separation of copper, iron and other heavy impurities from tin ore.
36th Ann. Rep. Roy. Cornwall Polyt. Soc., 1868, Falmouth, pp. 23-25.
Method proposed is to subject impure tin to the combined action of steam and air in conjunction with a little dilute acid.

1548. PEETZ, LE. Scheidung von Zinn und Blei aus Zinn-Blei-Legierungen.
Métallurgie, August 22, 1904, Paris, pp. 9.
Brief digest: Mg. Mag., Vol. 10, 1904, p. 439.
"One chemical and one electroyltic method of separating lead and tin in lead-tin alloys are given in considerable detail."

METALLURGY AND CHEMISTRY (Continued)

1549. PERRET, AUGUSTE. Zinc, étain, nickel, cobalt.
1903, Paris.
Petite Encyclopédie de chimie industrielle pratique.
Not available to the authors.

1550. PERSONNE, J. Mémoire sur les combinaisons de l'iode et de l'étain.
C. R. Acad. Sci., Vol. 54, 1862, Paris, pp. 216-220.

PIKE, E. R. *See* No. 715.

1551. PLATTE, GABRIEL. A discovery of subterranean treasure, viz., all manner of mines and minerals, etc.
1792, Philadelphia, pp. 9-10.
Operation of tin refining. "And as for refining of it, I am sure it cannot be done by any artifice."

1552. PLATTNER, C. A. Die Darstellung von Zinn- und Antimonblei auf den Königl. Sächs. Freiberger Hüttenwerken.
Jahrb. Berg. Hütt. Kön. Sachsen., 1883, Freiberg, pp. 1-18.

1553. RAWSON, S. G. The qualitative separation of arsenic, antimony and tin.
Chemical News, Vol. 75, 1897, London, p. 221.
Reprinted: Eng. Mg. Journ., Vol. 63, 1897, New York, p. 545.
Arsenic and antimony are precipitated from a mixture of oxalic and hydrochloric acids by hydrogen sulphide. Hydrides of arsenic and antimony are passed through a silver nitrate solution, and the antimonide of silver filtered out.

1554. RAY, JOHN. A collection of English words not generally used. With an account of the preparing and refining such metals and minerals as are found in England.
1768, London, 4th Ed.
The preparing and smelting or blowing of tin in Cornwall, pp. 131-134.

REYER, EDUARD. *See* No. 1354.

1555. RICHARDS, JOSEPH. Utilization of the wastes from the use of white metal.
Journ. Franklin Inst., Vol. 151, 1901, Philadelphia, pp. 446-447.
Also, Mg. Sci. Press, Vol. 82, 1901, San Francisco, p. 293.
Methods used by writer in removing tin from tin scrap, saving both tin and iron.

1556. RICHARDS, ROBERT H. Block tin resulting from distillation of a tin amalgam.
Trans. Amer. Inst. Mg. Eng., Vol. 11, 1882-1883, New York, pp. 235-236.

1557. RIEFFEL, —. Mémoire sur les combinaisons chimiques du cuivre avec l'étain, et sur leurs mélanges entre elles, constituant les alliages non chimiques de ces deux métaux.
C. R. Acad. Sci., Vol. 37, 1853, Paris, pp. 456-458.

ROSCOE, H. E. *See* No. 1568.

1558. ROSE, H. Ueber die Trennung des Zinns vom Antimon.
Ann. Physik. Chem., Vol. 71, 1847, Leipzig, pp. 301-304.
Extract: Ann. Mines, ser. 4, Vol. 15, 1849, Paris, pp. 129-130.

METALLURGY AND CHEMISTRY (Continued)

1559. ———. Ueber eine neue quantitative Bestimmung des Arseniks, Antimons und Zinn.
Journ. prakt. Chem., Vol. 44, 1848, Leipzig, pp. 117-118, Ann. Physik. Chem., Vol. 73, 1848, Leipzig, pp. 582-585.

1560. ROWE, LEONARD. Some chemical methods of treating ores.
66th Ann. Rep. Roy. Cornwall, Polyt. Soc., 1898, Falmouth, pp. 102-103.
Methods and difficulties of extracting tin from its associated minerals.

1561. SALET, G. Sur les spectres de l'étain et de ses composés.
C. R. Acad. Sci., Vol. 73, 1871, Paris, pp. 862-863.

1562. SALMON, —. Art du potier d'étain, 1788.
Not available to the authors.

1563. SANDALL, S. A. Preparation of protoxide of tin.
London and Edinburgh Philos. Mag. Journ. Sci., Vol. 12, 1838, London, p. 216.
Extract: Ann. Mines, ser. 3, Vol. 15, 1839, Paris, pp. 435-436.
Makes tin protoxide by heating the protochloride with sodium carbonate.

1564. SCHEURER-KESTNER, A. Sur les produits de l'oxydation du protochlorure d'étain et la dissolution de quelques oxydes dans le bichlorure.
C. R. Acad. Sci., Vol. 50, 1860, Paris, pp. 50-54.

1565. ———. Action l'oxygène sur le protochlorure d'étain. Dosage de l'étain par le permanganate de potasse.
C. R. Acad. Sci., Vol. 52, 1861, Paris, pp. 531-533.

1566. SCHULTZE, B. A new method of recovering tin from tin-plate scrap.
Polyt. Journ., Vol. 276, 1890, Stuttgart, p. 279.
Digest: Proc. Inst. Civ. Eng., Vol. 102, pt. 4, 1890, London, pp. 400-401.
Description of the process of stripping tin plate with acid ferric sulphate, acid stannic sulphate, dilute sulphuric acid or dilute hydrochloric acids.

1567. SCHUNCK, ED. Process for the use of tin-plate scrap in the manufacture of malleable iron.
Chem. Gaz., 1849, London; Amer. Journ. Sci. Arts, ser. 2, Vol. 9, 1850, New Haven, p. 279.
A patent issued to Ed. Schunck covers the stripping of tin plate scrap by an alkaline persulphuret; the recovery of the tin by the evaporation of the solution and the smelting of the residue; also the treatment of the iron by washing, packing in sheet iron cylinders, heating to welding heat and hammering.

1568. SCHUNCK, E., SMITH, R. A., and ROSCOE, H. E. On the recent progress and present condition of manufacturing chemistry in the South Lancashire district.
Rep. Brit. Ass. Adv. Sci., 31st meeting, Manchester, September, 1861, pt. 1, London, p. 119.
The manufacture of compounds of tin-chlorides and stannate of soda briefly treated.

SEXTON, A. HUMBOLT. *See* No. 1361.

1569. SLAGLE, ROBERT L. The double halides of tin with aniline and the toluidines.
Amer. Chem. Journ., Vol. 20, 1898, Baltimore, pp. 633-646.

METALLURGY AND CHEMISTRY (Continued)

1570. SLATER, W. Alliages de zinc, d'étain et de plomb.
Rev. Univ. Mines Mét. Trav. Publ. Sci. Arts Appl. Indust., sem. 2, Vol. 5, 1859, Liége and Paris, p. 187.
From "Chemical Gazette," 1858, London.

1571. SMITH, J. LAWRENCE. Analysis of alloys of tin and antimony.
Amer. Journ. Sci. Arts, ser. 1, Vol. 49, 1845, New Haven, p. 206.
Translation and abstract from "Chemical Gazette," August, 1844, London, p. 347. Giving Chevalier and Lassaigne's method.

1572. ———. Separation of tin from antimony.
Amer. Journ. Sci. Arts, ser. 2, Vol. 1, 1846, New Haven, p. 107.
Extract from Levol, A., Ann. Chim. Phys., January, 1845, Paris.

1573. SMITH, OBERLIN. Nails from tin scrap.
Trans. Amer. Inst. Mg. Eng., Vol. 17, 1889, New York, pp. 495-498.
Method of making good quality of nails, at one operation, directly from tin scrap.

SMITH, R. A. *See* No. 1568.

1574. STRENG, A. Ueber einige mikroskopisch-chemische Reaktion.
Neues Jahrb. Min., 1888, II, Stuttgart, pp. 142-146.
The testing of tin is treated.

1575. TALBOTT, J. H. On the quantitative separation of tin and tungsten.
Amer. Journ. Sci. Arts, ser. 2, Vol. 50, 1870, New Haven, pp. 246-247.
Separation depending upon reduction of stannic oxide by potassic cyanide, while tungstic trioxide is unaffected.

1576. TAYLOR, JOHN. On the smelting of tin ores in Cornwall and Devonshire.
Trans. Geol. Soc. London, Vol. 5, 1821, London, pp. 358-368.
Describes the smelting of "mine tin" in reverberatory furnaces and of "stream tin" in shaft-furnaces. The "block tin" of commerce is obtained from "mine tin" while "grain tin," a purer article, is obtained from "stream tin."

1576a. TERRELL, S. L. The final stages of tin and wolfram dressing.
Mg. Journ. Railw. Comm. Gaz., Vol. 83, 1908, London, p. 714, fig. 1.
Deals with the final treatment of tin and tungsten after concentration and takes up calcining and acid treatment.

1577. THIBAULT, P. J. The metallurgical treatment of complex tin sulphides.
Trans. Austr. Inst. Mg. Eng., Vol. 8, pt. 2, 1902, Melbourne, pp. 155-163.

1578. ———. The metallurgy of tin.
1907, London, pp. 250.
First appeared as a series of articles under the above heading in Austr. Mg. Stand., in 1907, Sydney and Melbourne.
Treats of the various branches of the metallurgy of tin, especially as practiced in Australia; methods of assaying tin ores and furnace products; the working of placer deposits by dredging and sluicing, and the reduction of ore.

1579. THIOLLIER, M. A. Visite aux mines et fonderies d'étain de Cornwall.
Bull. Soc. Indust. min., Vol. 14, 2d ser., 1885, Saint Etienne, pp. 575-587.
Also, Berg. Hütt. Zeit., Vol. 45, 1886, Leipzig, pp. 360-363.
Treated under heads: Reduction of mineral, treatment of slag left after first operation, refining of metal.

1580. THOMAS, V. Action du peroxyde d'azote sur les sels halogénés d'étain.
C. R. Acad. Sci., Vol. 122, 1896, Paris, pp. 32-35.

METALLURGY AND CHEMISTRY (Continued)

1580a. VAN OSDEL, EDGAR B. Determination of tin and antimony.

Eng. Mg. Journ., Vol. 87, 1909, New York, p. 850.

Gives a method which has proved satisfactory in the analysis of alloys such as type metal or of solutions containing only tin and antimony.

1581. VIGNON, LÉO. Sur l'étain.

C. R. Acad. Sci., Vol. 107, 1888, Paris, pp. 734-737.

Discussion of the precipitation of tin from tin-chloride, and of the easy oxidizability of the reduced metal.

1582. ———. Sur l'oxydabilité et le décapage de l'étain.

C. R. Acad. Sci., Vol. 108, 1889, Paris, pp. 96-98.

1583. WELLS, J. S. C. New method for the analysis of tin-ores, and for the separation of copper and cadmium.

School Mines Quart., Vol. 12, 1891, New York, pp. 295-296; Vol. 14, 1893, p. 156.

Reprint: Eng. Mg. Journ., Vol. 77, 1904, New York, p. 957.

Description of assay by reduction of cassiterite with HCl and metallic zinc. Note emphasizes fact that with some ores a piece of platinum must be used to effect complete reduction.

1583a. WESTON, E. M. *See* No. 3d.

1584. WIRTZ, L. British patent, 20,496 of 1902.

Eng. Mg. Journ., Vol. 76, 1903, New York, p. 362.

Recovering tin and zinc from scrap. "Dissolves the tin in hydrochloric acid and then immerses galvanized iron scrap in the solution of chloride of tin, the tin thus being precipitated and recoverable, while the zinc goes into solution as chloride."

1585. WITMER, LUTHER FERREE. The electrolytic determination of tin and its separation from antimony with a rotating anode.

1906, Lancaster, Pa., pp. 3-19.

1586. WORSEY, JAS. W. Recovery of tin from tinplate clippings.

Mg. Sci. Press, Vol. 83, 1901, San Francisco, p. 121.

Describes processes of stripping tin scrap with hydrochloric acid and with sodium sulphate, sulphuric acid and sulphur dichloride.

1587. WRIGHT, C. R. ADLER. On certain ternary alloys.

Proc. Roy. Soc. London, Vol. 45, 1889, London, pp. 461-481.

Alloys of lead, tin, and zinc, Vol. 48, 1891, pp. 25-32.

Mixtures of lead, zinc, and tin at higher temperatures, Vol. 49, 1891, pp. 158-163.

Alloys of bismuth, zinc, and tin.

A study showing the solubility of the metals in each other, and the mixtures and variations of the alloys upon cooling.

V. MINERALOGY

1588. Adger, J. B. Analysis of an anomalous variety of stannite (tin pyrites) from Cornwall.

Chem. News, Vol. 25, 1872, London, p. 250.

Analysis of a specimen of stannite showing some peculiarities.

1589. Anonymous. A new tin mineral.

Trans. Fed. Inst. Mg. Eng., Vol. 21, 1900-1901, Newcastle-upon-Tyne and London, p. 500.

New tin mineral called stokesite discovered in Cornwall. Colorless, concholdal fracture, formula, $H_4CaSnSi_2O_{11}$.

———. *See* Nos. 673 and 674.

1590. Arzruni, A. Künstlicher Kassiterit.

Zeitschr. Kryst. Min., Vol. 25, 1896, Leipzig. pp. 467-470.

"Cassiterite has been repeatedly observed as a furnace product, formed by the direct oxidation of tin." An occurrence of this kind is described by the author.

1591. Bauer, Max. Zinnstein.

Lehrbuch der Mineralogie, 1904, Stuttgart, pp. 556-558, figs. 3.

General description of tin ore as it occurs in different localities. Composition and crystalline form.

1592. Becke, F. Ueber die Krystallform des Zinnsteins.

Min. Mitth., 1877, Wien, pp. 243-260.

Digest: Neues Jahrb. Min., 1878, Stuttgart, pp. 76-78.

1593. Bernhardi, —. Bestimmung der Krystallisation einiger mineralischen Substanzen.

Tasch. ges. Min., 1807, Vol. 3, 1809, Frankfurt-am-Main, pp. 76-86.

On the crystal form of tin.

1594. Borgström, L. H. Ueber Kassiterit von Pitkäranta.

Zeitschr. Kryst. Min., Vol. 40, 1905, Leipzig, pp. 1-12, pl. 1.

Description of cassiterite crystals from Pitkäranta, Finland.

1595. Bourgeois, Léon. Sur la présence de la cassitérite dans les scories de la fonte du bronze et sur une nouvelle méthode de reproduction de cette espèce minérale.

Bull. Soc. franc. Min., Vol. 11, 1888, Paris, pp. 58-61.

1596. Brögger, W. C. Die Mineralien der Syenitpegmatitgänge der südnorwegischen Augit- und Nephelinsyenite.

Geol. För. Stockholm Förh., Vol. 9, 1887, Stockholm, p. 255.

Also, Zeitschr. Kryst. Min., Vol. 16, 1890, Leipzig, p. 61.

Nordenskiöldine, a very rare borate of calcium and tin, is described. Interesting because it directly connects tin and boron. Composition: $CaSnB_2O_6$. Mentioned as occurring on the island Arö.

MINERALOGY (Continued)

1597. CHAPMAN, E. J. Tinstone pseudomorphs.

London, Edinburgh, Dublin Philos., Mag. Journ. Sci., ser. 4, Vol. 6, 1853, London, p. 121.

A paragraph upon the composition of pseudomorphs of cassiterite after feldspar twins. They carried 43.6 and 55.46 per cent of metallic tin.

1598. COLLINS, J. H. On some Cornish tinstones and tin capels.

Min. Mag. Journ. Min. Soc., 1st paper, No. 17, Vol. 4, April, 1880, London, pp. 1-20; 2d paper, No. 18, Vol. 4, September, 1880, London, pp. 103-116; 3d paper, No. 24, Vol. 5, April, 1883, London, pp. 121-130.

Vol. 4 contains 12 plates, 5 of which are colored.

A description of Cornish tin-ores, and the minerals accompanying the cassiterite.

1599. CRONSTEDT, AXEL F. Mineralogy. Translated from Swedish with annotations, and an additional treatise on the blow-pipe by Gustav von Engestrom.

2d Ed. Vol. 2, 1788, London, pp. 618-643.

Tin is treated under heads: Its properties; native tin; calciform ores of tin; calciform tin ores crystallized; tin grains, calces of tin, mixed with metals; aurum musivum; observations on tin.

1600. DANA, J. D. A system of mineralogy.

1892, New York. (6th Ed.).

Mineralogical descriptions are given as follows: Cassiterite, pp. 234-236; nordenskiöldine, p. 875; stannite, p. 83.

An analysis is quoted from Leuchtenberg which shows the presence of tin in olivine found in a meteorite (p. 453) and a number of analyses showing the presence of tin in tantalite and columbite are given on pp. 732-733.

1601. DAUBRÉE, A. Sur la production artificielle de quelques espèces minérales cristallines particulièrement de l'oxyde d'étain, de l'oxyde de titane et du quartz. Observations sur l'origin des filons titanifères des Alpes.

Ann. Mines, 4th ser., Vol. 16, 1849, Paris, pp. 129-141.

Extrait par auteur, C. R. Acad. Sci., Vol. 29, 1849, Paris, pp. 227-229.

Extract: Bull. Soc. Geol. France, 2d ser., Vol. 7, 1849, Paris, pp. 267-276.

Report: C. R. Acad. Sci., Vol. 30, 1850, Paris, pp. 383-387.

Extract: Neues Jahrb. Min., 1849, Stuttgart, pp. 712-715.

Abstract: Amer. Journ. Sci. Arts, 2d ser., Vol. 9, 1850, New Haven, pp. 120-121.

The first part of this memoir gives the results of experiments made by Daubrée, with a view of imitating the processes by which Nature may have acted in forming minerals. Instead of using fluorides, which are not so easily prepared, Daubrée generally employed chlorides. From the great analogy of fluorides with chlorides he considers that the results obtained with the latter may be safely supposed to occur with the former. The first experiment consisted in passing a current of stannic chloride and a current of steam into a red-hot porcelain tube. Double decomposition took place, and crystals of stannic oxide were deposited on the sides of the tube. The crystals were found to belong to the rhombic system, which shows that stannic oxide, like titanic oxide, is dimorphous. The temperature of the end of the tube, where the crystals were deposited did not exceed 572° F. (300° C.), or, in other words was rather less than the melting point of lead. Titanic chloride, treated in the same way, gave crystals of brookite; whilst a deposit of vitreous and in part crystallized quartz was obtained from chloride of silica and steam.—C. Le Neve Foster.

MINERALOGY (Continued)

1602. ———. Recherches sur la production artificielle des minéraux de la famille des silicates et des aluminates, par la réaction des vapeurs sur les roches.

C. R. Acad. Sci., Vol. 39, 1854, Paris, pp. 135-140.

Cassiterite artificially prepared by passing the vapor of stannic chloride over heated lime.

———. *See* No. 1314.

DAVEY, RICHARD. *See* No. 1603.

1603. DAVEY, STEPHEN. Notice of pseudomorphous crystals of oxide of tin, found in Huel Coates mine, in St. Agnes in the year 1828.

Trans. Roy. Geol. Soc. Cornwall, Vol. 4, 1838, Penzance, pp. 484-485.

A short description of pseudomorphs after feldspar. Crystals in many stages of replacement were found.

Boase and Courtney (Bibliotheca Cornubiensis, Vol. 1, 1874, London, p. 106), state that this paper is really by Richard Davey, which is the name given in the index of the book in which the article occurs.

1604. DEVILLE, H. SAINT-CLAIRE. De la reproduction de l'étain oxydé et du rutile.

C. R. Acad. Sci., Vol. 53, 1861, Paris, pp. 161-164.

The crystallized oxide of tin obtained "by heating the amorphous oxide in a slow current of hydrochloric acid gas and again by a repetition of Daubrée's first process."

1605. DEVILLE, SAINT-CLAIRE H., and CARON, H. Sur un nouveau mode de production à l'état cristallisé d'un certain nombre d'espèces chimiques et minéralogiques.

C. R. Acad. Sci., Vol. 46, 1858, Paris, p. 768.

"The crystallized oxide of tin was obtained when stannic fluoride and boric oxide were heated together to whiteness." No details.

1606. DITTE, A. Sur quelques combinaisons du bioxyde d'étain.

C. R. Acad. Sci., Vol. 104, 1887, Paris, pp. 172-175.

FAWNS, SYDNEY. *See* No. 1320.

1607. FIELD, FREDERICK. On a specimen of tin ore hitherto undescribed.

Rep. Brit. Ass. Adv. Sci., Vol. 34, Bath, 1864, London, 1865, p. 27. (Notes and abstracts.)

Description of two specimens of "slime tin," a variety of "toad's-eye wood-tin (sic)."

1608. FOSTER, C. LE NEVE. On the place and mode of occurrence of the mineral Andrewsite.

Trans. Roy. Geol. Soc. Cornwall, Vol. 9, 1875, Penzance, pp. 163-164.

A hydrous iron-copper-phosphate occurring with tin ore at the West Phoenix Mine, Liskeard, Cornwall.

1609. FOULLON, H. Ueber krystallisirtes Zinn.

Jahrb. k. k. geol. Reichs., Vol. 34, 1884, Wien, pp. 367-384, wood cuts 2, pl. of figs. 1.

Abstract: Min. Mag. Journ. Min. Soc., Vol. 6, 1885, London, p. 148.

Found that crystals of tin obtained from the molten metal were of rhombic form, generally twinned. Such crystals may also be obtained by electrolytic deposition.

MINERALOGY (Continued)

1610. FOUQUÉ, F., and LÉVY, MICHEL. Synthèse des minéraux et des roches.
G. Masson, Ed., 1882, Paris, pp. 389-391.
Treats of the making of artificial cassiterite.

1611. FRENZEL, A. Ueber den Kylindrit.
Neues Jahrb. Min., 1893, II, Stuttgart, pp. 125-128.
Description of a rare tin mineral, occurring in Bolivia. Composition, $Pb_3FeSn_4Sb_2S_{14}$. (Cylindrite.)

1612. GADOLIN, S. A. Beobachtungen über einige mineralien aus Pitkaeranta in Finnland.
Verh. Russ. Kais. min. Ges., 1855-1856 (1856), St. Petersburg, pp. 184-196.
Descriptions of cassiterite crystals.

GENTH, F. A. *See* No. 820.

1613. GRANGER, A. Sur un sulfophosphure d'étain cristallisé.
C. R. Acad. Sci., Vol. 122, 1896, Paris, pp. 322-323.

1614. GREG, R. P., and LETTSOM, W. G. Mineralogy of Great Britain and Ireland.
1858, London, pp. 355-361.
Also, Neues Jahrb. Min., 1859, Stuttgart, pp. 186-189.
1. Oxide. Cassiterite: a. Forms of crystals. b. Analyses. c. Localities. d. Description of varieties, i. e. wood-tin, etc.
2. Sulphide in combination. Stannine.

1615. HAÜY, —. Suite de l'extrait du "Traité de Mineralogie."
Journ. Mines, Vol. 6, 1797, Paris, pp. 575-582.

1616. HEADDEN, WM. P. Stannite and some of its alteration products from the Black Hills.
Amer. Journ. Sci., ser. 3, Vol. 45, 1893, New Haven, pp. 105-110.
Discusses analyses of his own and of Titus Ulke's of stannite alterations from the Peerless and Etta mines. He thinks that some of these alteration products may be soluble in water and this may explain the origin of the tin in various pseudomorphs.

1617. ———. Some products found in the hearth of an old furnace upon the dismantling of the Trethellen tin works, Truro, Cornwall.
Proc. Colorado Sci. Soc., Vol. 6, 1897, Denver, pp. 74-85.
Abstract: Amer. Journ. Sci., ser. 4, Vol. 5, 1898, New Haven, pp. 93-96.
Author describes "wood-tin" (cassiterite) and compounds of arsenic, sulphur, iron, etc., formed in an old Cornwall furnace. He believes them sublimation products but Pearce believes them to be from slow cooling of magma.

———. *See* No. 1208.

HERMAN, R. *See* No. 968.

1618. CHANGED to 1505a.

1619. HUNT, ROBERT. Researches on the influence of magnetism and voltaic electricity, on crystallization, and other conditions of matter.
Mem. Geol. Surv. Great Britain, Vol. 1, 1846, London, pp. 443.
Muriate of tin and iodide of tin briefly treated.

MINERALOGY (Continued)

1620. HUTCHINSON, A. Ueber Stokesite ein neues Zinnmineral von Cornwall.
Zeitschr. Kryst. Min., Vol. 34, 1901, Leipzig, pp. 345-352, text fig.
Digest: Trans. Fed. Inst. Mg. Eng., Vol. 21, 1903, Newcastle-upon-Tyne and London, p. 590.
New tin mineral called stokesite, discovered in Cornwall. Colorless, conchoidal fracture. $H_4CaSnSi_2O_{11}$. The mineral may be regarded as a tetrasilicate of tin and calcium.

1621. JAMESON, ROBERT. Mineralogy.
3d Ed, Vol. 3, 1820, Edinburgh, pp. 155-169.
Tin ore is treated under: External characters; chemical characters; constituent parts; geognostic situation; geographic situation; uses; observations.

1622. JEREMEJEV, P. Krystalle des Zinnsteins aus Transbaikalien.
Verh. russ. kais. min. Ges., 2d ser., Vol. 11, St. Petersburg, pp. 273-280. [Russian.]

1623. ———. Krystalle von Zinnstein aus einigen goldführenden Sanden der Region des Jenissei.
Verh. russ. kais. min. Ges., 2d ser., Vol. 23, 1887, St. Petersburg, pp. 269-284.
Digests: Neues Jahrb. Min., 1890, I (Ref.), Stuttgart, p. 16; Bibl. géol de la Russie, par Nikitin, St. Petersburg, 1887 (1888), p. 79.

1624. KOHLMANN, W. Beobachtungen am Zinnstein.
Zeitschr. Kryst. Min., 1895, Vol. 24, Leipzig, pp. 350-365.
Compares many measurements of cassiterite crystals.

LACROIX, A. *See* No. 516.

1625. LAUNAY, LOUIS DE. Formation des gites métallifères ou métallogénie.
1905, Paris, pp. 129-130.
Brief summary in which he gives the ages of the tin deposits of the world.

LETTSOM, W. G., and GREG, R. P. *See* No. 1614.

1626. MATHER, W. W. Contributions to chemical science.
Amer. Journ. Sci. Arts, 1st ser., Vol. 27, 1835, New Haven, pp. 254-255.
Describes crystals of metallic tin formed from a saturated solution of tin chloride.

1627. MILLER, W. H. On the forms of the crystals of tin.
London, Edinburgh, Dublin Philos. Mag. Journ. Sci., Vol. 22, 1843, London, pp. 263-265.
Measurements of metallic tin crystals formed by electrolytic action.

1628. NÖGGERATH, J. J. Gegenden von Zinnwald und Altenberg.
Jenaische Lit. Zeit., 1823, p. 370.
Review: Zeitschr. Min. für 1825, Bd. I, Frankfurt-am-Main, pp. 558-563.

1628a. NORDENSKIÖLD, A. E. Beskrifning öfver de i Finland funna mineralier.
1855, Helsingfors, p. 102, 2d Ed., 1863, p. 26.
Quoted in Dana's "System of Mineralogy" (6th Ed. 1909), p. 236.
Describes ainalite, a cassiterite containing SnO_2 88.95, Ta_2O_5 8.78, Fe_2O_3 2.04 CuO 0.78=100.55 from Pennikoja in Somero, Finland, with tantalite and beryl in albite.

1629. PEARCE, RICHARD. Siliceous oxide of tin after quartz and allophane found in Cornwall.
44th Ann. Rep. Roy. Inst. Cornwall, 1862, pt. 1, Truro, pp. 19-20.
Not available to the authors.

MINERALOGY (Continued)

1630. ———. Notes on the occurrence of pseudomorphs of oxide of tin after some unknown mineral from Bolivia.

Trans. Roy. Geol. Soc. Cornwall, Vol. 13, 1906, pt. 2, Penzance, pp. 150-152.

Notice of cassiterite crystals that are apparently pseudomorphs, possibly after sulpho-stannites, as they are accompanied by what seem to be alteration products.

1631. PENFIELD, S. L. On canfieldite, a new sulphostannate of silver from Bolivia.

Amer. Journ. Sci., Vol. 47, 1894, New Haven, pp. 451-454.

Gives description and analysis of a sulphostannate of silver, containing germanium. Formula: $4Ag_2S(Sn,Ge)S_2$.

1632. PHILLIPS, J. ARTHUR. On the structure and composition of certain pseudomorphic crystals having the form of orthoclase.

Journ. Chem. Soc., Vol. 28, II, 1875, London, pp. 684-687.

Abstracts: Jahr. Chem. für 1875, Vol. 28, 1877, Giessen, p. 1249; Ann. Mines, ser. 7, Vol. 13, 1878, Paris, p. 516.

Results of the examination of some cassiterite crystals from St. Agnes mine.

1633. PHILLIPS, W. A description of the oxyde of tin, the production of Cornwall; of the primitive crystal and its modifications, including an attempt to ascertain with precision, the admeasurement of the angles, by means of the reflecting goniometer of Dr. Wollaston: to which is added, a series of crystalline forms and varieties.

Trans. Geol. Soc. London, Vol. 2, 1814, London, pp. 336-376, figures.

Review Tasch. ges. Min., Vol. 12, II, 1818, Frankfurt-am-Main, pp. 543-544.

The title is a fair digest of the article, which is a classic upon the subject.

1634. PHILLIPS, WILLIAM. On the measurements, by the reflecting goniometer, of certain primitive crystals; with observations on the methods of obtaining them by mechanical division along the natural joints of crystals.

Trans. Geol. Soc. London, Vol. 4, 1817, London, pp. 241-263; oxide of tin, pp. 244-246; about 500 words.

Gives method of cleaving cassiterite crystals by first heating them, so that faces parallel to all the sides of the common prism, its diagonals and faces of the primitive octohedron may be measured.

1635. PIRSSON, L. V. Mineralogical notes.

Amer. Journ. Sci., ser. 3, Vol. 42, 1891, New Haven, p. 407.

Description of crystals of hematite inclosing cassiterite, from Mina del Diablo, Durango, Mexico.

1636. PRIOR, G. T. On teallite, a new sulphostannite of lead from Bolivia; and its relations to franckeite and cylindrite.

Min. Mag. Journ. Min. Soc., Vol. 14, 1907, London, pp. 21-27.

"The new mineral occurs in thin graphite-like folia embedded in glistening kaolin, upon a dark grey matrix impregnated with iron-pyrites; on one specimen it is associated with a little wurtzite in thin plates, and on the other with a little galena." It is much like the other two minerals in physical character, but differs chemically, containing no antimony, only lead, tin and sulphur. Composition—$PbSnS_2$.

RAIMONDI, A. *See* No. 870.

Describes plumbostannite, a sulphide of lead, tin and antimony.

MINERALOGY (Continued)

1637. RAMMELSBERG, C. Ueber die chemische Zusammensetzung des Zinnkieses.

Ann. Physik. Chem., Vol. 88, 1853, Leipzig, pp. 603-608.
Digest: Neues Jahrb. Min., 1855, Stuttgart, pp. 72-73.
Gives a number of analyses of stannite from Zinnwald and Cornwall.

1638. REID, CLEMENT, and SCRIVENOR, J. B. The geology of the country near Newquay.

Mem. Geol. Surv. Great Britain, 1906, London, p. 39.
The so-called pseudomorphs of cassiterite after feldspar are really a replacement of that mineral by an aggregation of cassiterite, quartz and muscovite.

1639. ROSENBUSCH, H. Microscopical physiography of the rock-making minerals.

Translation and abridgement by Jos. P. Iddings, 1889, New York, pp. 151-152.
Microscopical-optical properties. Only one unquestioned occurrence noted of cassiterite occurring as a microscopical rock-making mineral, where it occurs with rutile as inclusions in the lithia-mica of the granite of Greifenstein.

SCHERTEL, A., and STELZNER, A. W. *See* No. 1643.

SCRIVENOR, J. B., and REID, CLEMENT. *See* No. 1638.

1640. SOLLY, R. H. Cassiterite, "sparable tin," from Cornwall.

Mg. Mag., Vol. 9, No. 43, 1891, New York, pp. 199-208, figs. 3.
Brief digest: Neues Jahrb. Min., 1892, II (Min.), Stuttgart, p. 15.
Descriptions of the tin crystals of various mines of Cornwall.

1641. SPENCER, L. J. Crystallized stannite from Bolivia.

Min. Mag. Journ. Min. Soc., Vol. 13, 1901, London, pp. 54-65, pl. 1. Read November 14, 1899.
Reprint: Zeitschr. Kryst. Min., Vol. 35, 1902, Leipzig, pp. 468-469, pl. 12, figs. 3-7.
Reviews the literature upon the crystallization of stannite, and shows from measurement of specimens from Bolivia that the mineral crystallizes in the scalenohedral-tetragonal system. Crystals 1-1.5 mm. across and had the composition Cu_2FeSnS_4. Reviews specimens from Oruro, Potosi, and Tatasi, Bolivia, and from Cornwall.

1642. STELZNER, A. W. Ueber Franckeit, ein neues Erz aus Bolivia.

Neues Jahrb. Min., 1893, II, Stuttgart, pp. 114-124.
Composition, $Pb_5FeSn_2Sb_2S_{14}$.

1643. STELZNER, A. W., and SCHERTEL, A. Ueber den Zinngehalt und über die chemische Zusammensetzung der schwarzen Zinkblende von Freiberg.

Jahrb. Berg. Hütt. Kön. Sachsen, 1886, Freiberg, pp. 52-70, pl. of figs. 1.

1644. THIBAULT, P. J. Conradite. A new mineral compound of tin.

Austr. Mg. Stand., Vol. 33, 1905, Sydney and Melbourne, pp. 124-125.
Discovered by author at the Conrad Mines, Howell, New South Wales, in 1902. Composition, $7SnO_2+Fe_2O_3$, being a compound of stannic and ferric oxides containing: Tin, 68.44 per cent, iron 9.2 per cent, oxygen 22.32 per cent. Absolutely insoluble in nitric, hydrochloric, sulphuric and hydrofluoric acids and aqua regia. Specific gravity about 6.2; not attracted by the magnet.

1645. TRECHMANN, C. O. On a probably dimorphous form of tin; and on some crystals found associated with it.

Min. Mag. Journ. Min. Soc., Vol. 3, 1879, London, pp. 186-192.
Two forms of crystals apparently obtained by electrolytic and dry methods of manufacture of metallic tin crystals.

MINERALOGY (Continued)

TWEEDY, W. M. *See* No. 478.

Pseudomorphs after feldspar.

1646. ULKE, TITUS. A new tin mineral in the Black Hills.

Trans. Amer. Inst. Mg. Eng., Vol. 21, 1893, New York, pp. 240-241.

Mr. Ulke has named this new tin mineral "Cuprocassiterite." "Cuprocassiterite is a light-yellowish to malachite-green mineral of an earthy fracture, dull glance, and, in the Etta mine, found with cassiterite filling cavities in a compact quartz gangue. Hardness, 3, specific gravity, nearly 5, streak, white."

Analysis: 62 per cent Sn, 13 per cent Cu, and 6 per cent H_2O, with traces of iron and silica.

1647. VLAANDEREN, C. L. Bepaling van de hoeveelheid tinoxyde in tinerts aanwezig.

Jaarb. Mijnw. Ned. Oost-Indië, 1872, I, Amsterdam, pp. 269-273.

1648. VOGT, J. H. L. Künstliche Bildung von Kassiterit durch einen einfachen Oxydationsprocess ohne Gegenwart von sogenannten "agents minéralisateurs."

Zeitschr. Kryst. Min., Vol. 31, 1899, Berlin, pp. 279-280.

1649. WOOLNOUGH, W. G. Symmetrically distorted crystals from Western Australia.

Journ. Proc. Roy. Soc. New South Wales, Vol. 35, 1901, Sydney, pp. 332-335, pl. 1.

Crystals of cassiterite from Pilbarra, West Australia, are so distorted as to appear monoclinic. Intergrown with monazite which the author thinks may have caused the distortion.

See Molengraaff, G. A. F. (No. 1052) for similar crystals from Swaziland, also, Lacroix, A. (No. 516) for like distorted crystals from France.

VI. MINING AND MILLING

1650. Anonymous. The losses in dressing Cornish tin ores.
Eng. Mg. Journ., Vol. 55, 1893, New York, p. 256.
Brief description of improved methods and results gained.

———. *See* No. 312.

1651. Carcanagues, —. Mémoire sur la préparation mécanique du minerai d'étain dans le Cornwall.
Ann. Mines, ser. 7, Vol. 14, 1878, Paris, pp. 205-229.

Chamberton, Arthur G. *See* No. 1310.

1652. Collins, J. H. On the use of the impact screen in tin dressing.
Trans. Inst. Mg. Met., Vol. 15, 1905-1906, London, pp. 324-325.
Mg. Journ. Railw. Comm. Gaz., Vol. 78, 1906, London, p. 511.
The author reports that the impact screen is for the first time, as far as is known, being used for tin dressing at Wheal Kitty mine, and with very satisfactory results.

1653. Commans, Robert E. The concentration and sizing of crushed minerals.
Proc. Inst. Civ. Eng., Vol. 116, 1894, London, pp. 3-66. Discussion and correspondence pp. 67-112, figs. 30.
An account of methods and apparatus used in treatment of ores including tin ores, to render them marketable.

Fawns, Sydney. *See* No. 1320.

1654. Ferguson, Henry T. On the mechanical appliances used for dressing tin and copper ores in Cornwall.
Proc. Inst. Mech. Eng., 1873, London, pp. 119-127.
Discussion, pp. 127-132.
Treated under the heads: Tin dressing, stamping, buddling, calcining, treatment of slimes, pulverizing.

1655. Frecheville, R. J. The results obtained by the Cornish system of dressing tin ore, with observations thereon.
Trans. Mg. Ass. Inst. Cornwall, Vol. 1, 1887, Camborne, pp. 93-104.
Reprint: Eng. Mg. Journ., Vol. 40, 1885, New York, pp. 416-417.
A paper discussing the amount of tin saved at the mines, the amount caught by the stream works, and amount finally lost.

1656. Henwood, W. J. On the manipulation to which the ores of tin and copper are subjected in the central mining district of Cornwall.
Trans. Roy. Geol. Soc. Cornwall, Vol. 4, 1838, Penzance, pp. 145-165.
Description of stamps, buddles, kieves, etc., used. Also roasting furnace and jigs.

1657. Hicks, James. Treatment of slime tin.
Trans. Mg. Ass. Inst. Cornwall, Vol. 4, 1893-1895, Camborne, pp. 111-123.
Discussion, pp. 123-137, figs. 4. Read December 20, 1892.
"The increasing importance of the careful treatment of slime tin arises from the fact that as our mines increase in depth the tin in the stone becomes finer in grain." Mentions the fact that ore is being crushed finer than formerly, and discusses the loss of slimes in the Red River and the recovery by streamers.

MINING AND MILLING (Continued)

KUNHARDT, WHEATON B. The practice of ore dressing in Europe.

School Mines Quart., 1884, New York, pp. 103-104.

Describes calcining, to fissure tough rock, as practiced in tin districts of Saxon Erzgebirge; and roasting, to decompose arsenopyrite in tin ore.

MACALISTER, DONALD A. Notes on ore dressing in Cornwall.

Summ. Progr. Geol. Surv. United Kingdom for 1904 (1905), London, pp. 153-163, fig. 1.

Present high price of tin makes it probable that some abandoned mines could be profitably worked by modern methods. In early days lodes were worked for only one of the metalliferous minerals, rest thrown to waste. Can be made to cover cost of mining and dressing if it carries only a little under 1 per cent (22.4 pounds per ton) of "black tin" which generally contains over 90 per cent cassiterite and yields on smelting about 65 per cent of metallic tin.

PEARCE, RICHARD. Losses in vanning tin ores.

Mg. Journ. Railw. Comm. Gaz., Vol. 77, 1904, London, pp. 116-117.

Gives results of experiments in vanning material containing a known amount of cassiterite.

———. *See* Nos. 1546 and 1547.

PHILLIPS, JOHN. Improvements in dressing of tin.

Mg. Journ. Railw. Comm. Gaz., Vol. 15, 1845, London, p. 184, fig. 1.

Explanation of diagram of improved furnace for calcining tin ore.

SEXTON, A. HUMBOLT. *See* No. 1361.

SKEWES, EDWARD. Magnetic separation of tin and wolfram at Gunnislake Clitters.

Eng. Mg. Journ., Vol. 76, 1903, New York, pp. 424-425, 700 words.

After crushing and separating the concentrates are calcined and then run through the magnetic separator. One magnet picks up the iron oxide made from pyrites, and a second picks out the wolframite. Tin ore sold ranks as best in Cornwall. Yield of tin 0.378 per cent, wolframite 0.72 per cent.

TAYLOR, J. On the economy of the mines of Cornwall and Devon.

Trans. Geol. Soc. London, Vol. 2, 1814, London, pp. 309-327.

A general treatise upon the business methods of mines in Cornwall and Devon, including operations of the tin mines.

TERRELL, S. L. The final stages of tin and wolfram dressing.

Mg. Journ. Railw. Comm. Gaz., Vol. 83, 1908, London, pp. 714-715, figs. 2.

"Deals with tin and wolfram after concentration, considering fine and rough concentrates."

THOMAS, CHAS. Tin dressing.

50th Ann. Rep. Roy. Cornwall Polyt. Soc., 1882, Falmouth, pp. 182-186. Discussion pp. 186-193.

Treats of methods and improvements that will reduce the waste of tin resulting from dressing.

THOMAS, R. ARTHUR. On crushing and concentrating at Dolcoath mine, Cornwall.

Trans. Inst. Mg. Met., Vol. 7, 1899, London, pp. 175-180. Discussion, pp. 180-190.

A general description of the treatment of tin ore at the mine; crushing and concentration, roasting and reconcentration, with accounts of experiments.

MINING AND MILLING (Continued)

1667. TREGAY, W. All about tin; an enquiry.
Mg. Journ. Railw. Comm. Gaz., Vol. 50, 1880, London, pp. 49, 76, 105, 190, 221.
Treats of tin dressing.

1668. WILLIAMS, R. H. Tin dressing and Williams's buddle.
Mg. Journ. Railw. Comm. Gaz., Vol. 47, 1877, London, pp. 487-488, 684-685, 796.
Description of, and results obtained with Williams's buddle.

VII. STATISTICS

1669. ANONYMOUS. Statistics on tin in Cornwall, etc.

Trans. Roy. Geol. Soc. Cornwall, Penzance, Vol. 1, 1818, pp. 250-251. Vol. 2, 1822, pp. 424-427. Vol. 3, 1827, pp. 339-341. Vol. 4, 1838, p. 491. Vol. 6, 1846, p. 358. Vol. 7, 1865, p. 112. Vol. 8, 1871, pp. 442, 443, 444, 446, 447, 448, 452-453, 472, and table 14, Vol. 10, 1887, pp. 153-155.

1670. ———. La situation de l'étain.

Métallurgie, Vol. 32, 1901, Paris, pp. 1013, 1015.
Gives statistics of important tin producing countries from 1885 through 1899.

1671. ———. Supplement to government gazette of Western Australia, No. 66.

M. S. No. 61, Perth, November 25, 1904, pp. 2963-2969.
General return of ore and minerals, other than gold, showing the quantity produced and the value thereof during 1904 and previous years.
The statistics of tin production are published annually in this form.

1672. ———. Japan in the beginning of the 20th century.

Published by Imperial Japanese Commission to Louisiana Purchase Exposition, 1904, pp. 293, 321.
Gives the output of tin by years from 1892 to 1902, inclusive.

1673. ———. Return showing the quantity and value of tin exported from Tasmania from 1880 through 1904, compiled from customs returns only, and tin ore produced during 1905.

Rep. Secr. Mines, Tasmania, for 1905 (1906), Hobart, p. XVII.

1674. ———. Billiton and Banca tin.

Mg. World, Vol. 24, 1906, Chicago, p. 778.
Giving the Banca tin production from 1881 to 1906 (25 years) as 184,349 long tons. During last ten years from 1896 to 1906 Billiton produced 46,938 long tons.

1675. ———. Tin from the Malay Peninsula.

Mo. Bull. Int. Bur. Amer. Repub., Vol. 23, November, 1906, Washington, D. C., pp. 1179-1180.
As the sliding scale of prices for Bolivian tin is regulated by the quotations for the Straits Settlements product, a report on the subject by United States Consul General, D. F. Wilber is given.

1676. ANNUAL Report, Department of Mines, New South Wales, from 1875.

Sydney.
Gives statistical and other information about the tin output of New South Wales.

1677. COGHLAN, T. A. A statistical account of the seven colonies of Australasia.

1892, Sydney, pp. 142-145.
Tin of New South Wales, Tasmania, Queensland and Victoria described briefly. Production for 1890 given. Fluctuations in the price of tin.

STATISTICS (Continued)

1678. ———. A statistical account of the seven colonies of Australasia. 1899-1900.

1900, Sydney, pp. 1-836, map 1.
Includes tin production in Australia.

1679. ———. Tin. A statistical account of Australasia and New Zealand, 1903-1904.

Sydney, pp. 933-936.
New South Wales, p. 934; Western Australia, p. 935; Victoria, p. 935; South Australia, p. 935; Queensland, p. 935; Tasmania, p. 934.

1680. Collins, J. H. Seven centuries of tin production in the west of England.

Trans. Mg. Ass. Inst. Cornwall, Vol. 3, 1892, Camborne, pp. 173-193.
"Estimates the total produce of metallic tin in the West country between 1201 and 1800 A. D. to be 875,000 tons, from which it may be reckoned that 711,000 tons were yielded between 1201 and 1750 A. D., from both Cornwall and Devon. Of 283,000 tons of tin yielded between 1201 and 1600 A. D., 75,000 were derived from tin stream gravels; and of 573,800 tons yielded between 1601 and 1800 A. D., 473,000 tons were derived from tin stream gravels."

1681. Earl of Mount Edgcumbe. Production of tin in Cornwall.

Journ. Roy. Inst. Cornwall, Vol. 8, 1886, Truro, pp. 8-9.
The tin produced in Cornwall from 1873-1883 given.

1682. Ehrenwerth, J. von. Production an Zinn in den Jahren 1881 bis 1890.

Oest. Zeitschr. Berg. Hütt. Vol. 41, 1893, Wien, p. 220.
Statistics showing the tin production of the world for the years 1881 to 1890.

1683. Engineering and Mining Journal.

Since Vol. 17, 1874, New York.
Annually collects statistics of the world's tin production.

1684. Estadística Minera España.

Annual, Madrid.
Tables showing production of tin producing provinces of Spain.

1685. Great Britain. Home Office.

London.
Title varies: 1882, Mineral statistics of the United Kingdom of Great Britain and Ireland.
1883, Mines and minerals. Summaries of the reports of the inspectors of mines. . . . and mineral statistics of the United Kingdom of Great Britain and Ireland.
1884-1887, Mines and minerals. Mining and mineral statistics of the United Kingdom of Great Britain and Ireland.
1888-1894, Mines and minerals. Mineral statistics of the United Kingdom of Great Britain and Ireland with the Isle of Man. . . .
1895-1896, Mines and quarries. Mineral statistics of the United Kingdom of Great Britain and Ireland with the Isle of Man.
1897, Mines and quarries: General report and statistics. . . . . Issued in four parts: Pt. I. District statistics. Pt. II. Labor. Pt. III. Output. Pt. IV. Colonial and foreign statistics.
General statistics of tin.

1686. There is no reference bearing this number.

1687. Hunt, Robert. On the present state of tin production and the tin trade.

Rep. Proc. Min. Ass. Cornwall and Devon, for 1874 (1875), Truro, pp. 35-40.

STATISTICS (Continued)

Gives number of productive tin mines, quantity of ore produced, and average price per ton, of the Cornwall mines from 1864-1873; also production and price of foreign tin for same years.

———. Mineral statistics of the United Kingdom from 1853 through 1880.

London.

JAARBOEK van het Mijnwezen in Nederlandsch Oost-Indië, from 1872, Amsterdam to 1899. Batavia since 1900.

Publishes statistics of tin produced in East Indies.

KOULIBINE, S. La production minière et métallurgique de la Russie en 1885 (Bulletin).

Rev. Univ. Mines, Mét. Trav. Publ. Sci. Arts Appl. Indust., ser. 3, Vol. 4, 1888, Paris and Liége, p. 88.

(Extrait d'un rapport de M. Koulibine.)

Étain—Une seule usine, située dans le gouvernement de Wyborg, s'est occupée du traitement de l'étain. Elle n'a produit que 14,087 kg. de métal raffiné. (Whole reference.)

———. La production minerale et metallurgique de la Russie en 1887.

Rev. Univ. Mines Mét. Trav. Publ. Sci. Arts Appl. Indust., ser. 3, Vol. 11, 1890, Paris and Liége, p. 314.

(Extrait du rapport de M. Koulibine.) 10^t 351 d'étain ont été retirées du traitement de 1738^t, de minerais à l'usine de Pitkäranta (Finland). (Whole reference.)

———. Tableau de l'industrie minérale de la Russie en 1888-1889.

Rev. Univ. Mines Mét. Trav. Publ. Sci. Arts Appl. Indust., ser. 3, Vol. 16, 1891, Liége and Paris, p. 214.

Tin production in Pitkäranta (Finland); 1888, 1.186 poods; 1889, .721 pood.

MACALISTER, DONALD A. Total quantity of tin, copper and other minerals produced in Cornwall, particularly with regard to the quantities raised from each parish.

Summ. Progr. Geol. Surv. Great Britain for 1906 (1907), London, pp. 132-139.

METALLGESELLSCHAFT. Comparative statistics of lead, copper, tin, silver, nickel, aluminum and quicksilver, from 7th year, 1890-1899.

Frankfort-on-the-Main.

Publishes estimates of the world's production and consumption of tin.

REPORT on Mineral Industries in the United States at the eleventh census, 1890.

1892, Washington, D. C., p. 249.

For 1889, California, South Dakota, Virginia.

MINERAL Industry.

Vol. I, 1892, New York; New York and London since Vol. 3, 1895.

Publishes annual articles on the production of tin throughout the world.

MINERAL Statistics of Victoria, 1873-1877 to 1885-1888, also Reports and Statistics since 1890-1891.

Melbourne.

STATISTICS (Continued)

1698. PLUMMER, JOHN. Australian mineral production and export.
Mg. World, Vol. 25, 1906, Chicago, p. 430.
Statistics of tin production during 1904 and 1905.

ROLKER, CHAS. M. *See* No. 1357.

1699. SPARGO, T. Statistics and observations on the mines of Cornwall and Devon.
1864, London.
Not available to the authors.

See Tasmania, Government geologist No. 1134.

1700. TRASENSTER, PAUL. Revue economique et statistique.
Rev. Univ. Mines Mét. Trav. Publ. Sci. Arts Appl. Indust., ser. 2, Vol. 13, 1883, Paris and Liége, p. 480.
Estimates the tin production of the world during 1879, 1880 and 1881.

VICTORIA. *See* No. 1222.

WATSON, J. Y. *See* No. 483.

WEEKS, JOSEPH D. *See* No. 1372.

1701. WHITNEY, J. D. The metallic wealth of the United States.
1854, Philadelphia, p. 510.
Abstract: Zeitschr. Berg. Hütt. Sal. preuss. Sta., Vol. 2, 1854, Berlin, p. CXXIII.
Table giving the mineral production of the world for the year 1854.

INDEX

[Prepared by Lancaster D. Burling.]

Reference Number

———, R. D. 796
Aaron, C. H. 1428
Abbaretz, *see* France, Lower Loire.
Abbott, George, Jr. 309
Aberfoil River, *see* New South Wales.
Adair, James B. 7
Adams, Robert 795
Acamistla, *see* Mexico, Guerrero.
Adger, J. B. 1588
Aeschynite, *see* Association of tin with.
Africa:
  Beck on tin deposits in southern Africa 1
  Gibson on tin in metamorphic areas of southern Africa 2
  Louis on tin in 1340
  Recknagel on the origin of the South African tin deposits 3a
  Voit on the economically valuable mineral deposits of South Africa. 3c
  See also Cape Colony, French Kongo, Kamerun, Kongo, Madagascar, Nigeria, Pretoria, Swaziland, Transvaal, South Africa.
Agricola, Georgius 1277
Aguas Calientes, *see* Mexico.
Aguilera, José G. 751, 752, 753
Ainalite, Nordenskiöld on in Finland 1628a
Akkeringa, J. E. 73, 121
Akwa-Ibama district, *see* Nigeria.
Alabama, tin in 4, 1281
  Benedict on tin in 1200, 1301
  Benedict on the Broad Arrow Mine near Ashland, Clay County 5
  Broad Arrow Mine 5
  Coosa County, tin in 6
  Day on tin in 1203a
  Kemp on tin in 1213
  Phillips on tin in Coosa County 6
  Rolker on tin in 1357
  See also United States.
Alaska, tin in 7, 12a, 12b, 1196, 1292
  Adair on tin deposits of the York region 7
  Anikovik River, tin on 8
  Beales on tin in Seward Peninsula 13

Alaska—Continued. Reference Number
Bell on tin on Cassiterite Creek, a branch of Lost River..... 16
Bell on tin near Port Clarence..... 14
Bell on tin in Seward Peninsula and on Lost River..... 15
Brooks on reconnaissances in the Cape Nome and Norton Bay regions 17
Brooks on tin on Buhner Creek..... 17
Brooks on tin localities in..... 18
Buck Creek, occurrence of tin on.....12c, 13, 22, 28b, 30
Buhner Creek, tin on.....8, 17, 24
Cape Mountain, occurrence of tin in.....12c, 18, 22
Cape Nome region, reconnaissance of 17
Cape Prince of Wales, tin on.....13, 25
Collier on tin in, *see* No. 1364.
Collier on tin in Seward Peninsula.....19, 23
Collier on tin in the York region.....20, 21, 22
Courtis on tin placers 12 miles northeast of York..... 24
Ears Mountain, occurrence of tin in.....12c, 18, 29b
Fairbanks region, tin in..... 23
Fawns on tin in..... 1320
Fay on area, climate, vegetation, geology, tin deposits, mining, economic conditions, and prices of provisions in..... 25
Fay on tin deposits of Cape Prince of Wales..... 25
Fillery Creek, tin on..... 30
Garrison on tin on York River..... 1207
Hess on tin deposits of York region, Seward Peninsula.....26, 27
Hill on history of the York tin mines, Seward Peninsula..... 28a
Hill on tin deposits of the York region..... 28
Jacobs on the mineral exhibit at the Alaska-Yukon-Pacific Exposition 28b
Knopf on production of tin in Seward Peninsula through 1908..... 28b
Knopf on tin deposits of Seward Peninsula.....29, 29a
Knopf on tin minerals of Alaska.....29b
Lost River, occurrence of tin on.....12c, 29b
Lost River region, tin in.....9, 13, 15, 16, 18, 22, 31
Newland on tin in.....1346, 1347
Newland on tin on Buck and Fillery Creeks..... 30
Newland on tin in Lost River district..... 31
Norton Bay region, reconnaissance of..... 17
Ohly on tin in..... 1215
Pavlov on tin in..... 32
Pavlov on tin in York region..... 1216
Port Clarence, tin near..... 14
Rickard on tin deposits of the York region..... 33
Seward Peninsula, tin in.....7–31, 33, 35
Seward Peninsula, York tin mines, history of..... 28a

Alaska—Continued. Reference Number
Seward Peninsula, *see* also York, Cape Nome, Norton Bay, Cape Prince of Wales, Port Clarence, and Lost River regions.
Struthers and Pratt on tin in..... 1364
T———— on tin in..... 34
Walcott on discovery of tin near York..... 35
York, tin 12 miles northeast of..... 24
York region, tin in....7, 8, 17, 18, 20, 21, 22, 24, 26, 27, 28, 33, 35, 1193, 1216
York River, tin on..... 1207
Albany, *see* Victoria.
Albite, *see* Association of tin with.
Alexandria, Smirke on tin trade between Britain and..... 1417
Allanite, *see* Association of tin with.
Allard 1429
Allen, Alfred H..... 1430
Allen, D. K..... 754
Allen, J. F..... 1431
Allen, Tho. 579
Allier, *see* France.
Allophane: tin oxide after quartz and allophane in Cornwall..... 1629
Alloys, Wright on (a general article)..... 1587
Alloys of tin:
Allen on alloy with copper and manganese..... 1431
Allen on estimation of tin in..... 1430
Analysis of 1433, 1449, 1450, 1531a, 1571, 1580a
Babbitt metal, composition, uses, and analyses.....1531a
Berthier on analysis of.....1449, 1450
Billings on properties of iron alloyed with tin and other metals.... 1452
Blake on 1202
Cahours on alloys of tin and sodium..... 1460
Graham on 1324
Hanks on the alloys of tin and their uses..... 218
Headden on the formation of the alloys of tin and iron, with description of some new alloys..... 1502
Heycock and Neville on the constitution of copper-tin alloys..... 1504
Meade on composition, uses, and analysis of babbitt metal alloys...1531a
Mengin on separation of tin and antimony in..... 1533
Parry on eutectic alloy of lead and tin.....1545a
Peetz on separation of tin and lead in tin-lead alloys..... 1548
Plattner on alloys of lead with tin and antimony..... 1552
Properties of the alloys of copper and tin..... 1433
Rieffel on the alloys of copper and tin..... 1557
Schultz on production and application of solder..... 1359
Slater on alloys of zinc, tin, and lead..... 1570
Smith (J. L.), on analysis of..... 1571

Alloys of tin—Continued. Reference Number
Solder, its production and application 1359
Specific gravities of 1433
Stress tests of 1433
Van Osdel on analysis of alloys of tin and antimony 1580a
With antimony 1533, 1552, 1580a
With bismuth 1587
With copper 1431, 1433, 1504, 1557
With iron 1452, 1502
With lead 1545a, 1548, 1552, 1570, 1587
With manganese 1431
With sodium 1460
With zinc 1570, 1587
Wright on alloys of lead, tin, and zinc at low and high temperatures, and on alloys of bismuth, zinc, and tin 1587
Almandite, *see* Association of tin with.
Altenberg, *see* Saxony.
Alum, Hennecke on occurrence in Persia 864
Aluminum, Douglas on metallurgy of 1204
Precipitation of tin on, in estimation of tin in salts of tin 1493
World statistics, 1890 to date 1694
Amalgam, distillation of tin amalgam 1556
Ambatofangehana, *see* Madagascar.
Amblygonite, *see* Association of tin with.
Ambohimanga, *see* Madagascar.
Amherst, *see* Burmah.
Anaberg Revieren, *see* Saxony.
Analyses of tin 1290, 1432
Adger on stannite from Cornwall 1588
Banka 77
Bergemann on tin from Xeres, Mexico 764, 1446
Berthier on analysis of a tin alloy 1449, 1450
Betts on 225
Brown on cassiterite from Rockbridge County, Virginia 1240
Caillaux on tin from Tuscany 618
California 787
Campbell on cassiterite from Rockbridge County, Virginia 1241
Ceylon 258
Collins on the crust of a block of "Jews' tin" 362
Cornwall 442, 1588
Dana on tin in tantalite, columbite, and in meteoric olivine 1600
Day on cassiterite in Black Hills, South Dakota 1005
Dunstan on tin from Madagascar 647
Dunstan on tin from northern Nigeria 857, 858
Dunstan on stream tin from Ceylon 258

nalyses of tin—Continued. Reference Number
Dykes on analyzing tin slags..... 1483
Genth on cassiterite near Kings Mountain, North Carolina..... 244
Genth on two concentrates from San Jacinto, California..... 787
Headden on tantalum in tin from South Dakota and the Carolinas.. 1208
Headden on tapiolite from South Dakota..... 1208
Ingalls on ten analyses of Mexican tin ore..... 776
Lampadius on analyzing the minerals of tin..... 1515
Liversidge on tin from Elsmore mine, Inverell, New South Wales.. 830
Madagascar 647
Malay Peninsula, Pahang..... 674
Mallett on analysis of tin pyrites..... 1531
Meade on analysis of babbitt metal alloys.....1531a
Mexico 776
Mexico, Xeres.....764, 1446
Muller on analysis of tin ores..... 1539
Newberry on cassiterite from Victoria..... 1232
New South Wales, Elsmore mine..... 830
Nigeria, stream tin from.....856, 857
North Carolina.....244, 1208
Peru, Cajatambo, ores from..... 866
Phillips on rocks in which mineral deposits occur in Cornwall..... 442
Schaeffer on tantalite from the Black Hills, South Dakota..... 1017
Simpson on tin in Western Australia..... 1267
South Carolina..... 1208
South Dakota.....1005, 1017, 1023, 1208
Todd on tin ore from South Dakota..... 1023
Tuscany 618
Van Osdel on analysis of alloys of tin and antimony.....1580a
Victoria 1232
Virginia 1240, 1241
Wells on analysis of tin ores..... 1583
Western Australia..... 1267
See also Chemistry of tin, and assays of tin.
See references Nos. 1428–1587.
nchor mine, *see* Tasmania.
ndalusite, *see* Association of tin with.
ndover, *see* New Jersey.
ndrews, E. C..... 797
ndrewsite, Foster on place and mode of occurrence of..... 1608
nikovik River, *see* Alaska.
njou, *see* France.
nnan River, *see* Queensland.
ntananarivo, *see* Madagascar.
ntequera mine, *see* Bolivia.

Antimony: Reference Number
Action on chlorides of mercury ... 1465
Alloys of, analysis ... 1571
Alloys of lead and ... 1552
Alloys of tin and ... 1533, 1552, 1580a
Assay of ... 1545
Association of tin with ... 166, 172, 180a, 225, 496, 1086
Bechamp and Saintpierre on separation of gold and platinum from tin and antimony ... 1445
Berglund on the qualitative separation of tin, antimony, and arsenic. 1447
Boucard on separation of gold and platinum from tin and antimony. 1455
Bunsen on the separation of arsenic from antimony and tin ... 1459
Capitaine on action of tin, arsenic, antimony, and sulphur on the chlorides of mercury ... 1465
Clarke on separating tin from arsenic, antimony, and molybdenum. 1467
de Koninch and Lecrenier on the qualitative separation of gold and platinum from arsenic, antimony, and tin ... 1474
Dewey on Clarke's method of separating tin from arsenic and antimony ... 1477
Douglas on metallurgy of ... 1204
Gay-Lussac on the separation of tin from ... 1495
Hennecke on occurrence in Persia ... 864
Henz on separation of antimony and tin ... 1503
Levol on quantitative separation of tin and ... 1519
Mengin on separation from tin in alloys ... 1533
Metallurgy of ... 1204
Parry on assay of ... 1545
Persia ... 864
Plattner on alloys with lead and tin at Freiberg, Saxony ... 1552
Rawson on qualitative separation of arsenic, antimony, and tin ... 1553
Rose on quantitative determination of tin, arsenic, and antimony ... 1559
Rose on separation of tin and ... 1558
Separation from gold, platinum, and tin ... 1445, 1455
Separation from gold, platinum, tin and arsenic ... 1474
Separation from tin ... 1495, 1503, 1519, 1558, 1572
Separation from tin in alloys ... 1533, 1552
Separation from tin and arsenic ... 1447, 1459, 1477, 1553, 1559
Separation from tin, arsenic, and molybdenum ... 1467
Smith (J. L.) on analysis of alloys of ... 1571
Smith (J. L.) on separation of tin from ... 1572
Tasmania ... 1079
Van Osdel on analysis of alloys of tin and ... 1580a
Witmer on the separation of tin from ... 1585
Apacheta mine, *see* Bolivia.
Apatite, association of tin with ... 227, 1009, 1314
Vogt on occurrence of ... 1370

Reference Number

Appleton, W. S. 1374
Approuague River, *see* French Guiana.
Araca, *see* Bolivia.
Arba mine, *see* Tasmania.
Arecayo mine, *see* Bolivia.
Argall, Wm. 330
Argentiferous galena, *see* Association of tin with.
Argentina:
  Castro on tin, gold, silver, copper, lead, and bismuth deposits in province of Salta 37
  Catamarca, Tinogasta, tin near 38
  Hoskold on mines, mining, metallurgy, and mining laws, etc., of ... 38
  Hoskold on tin near Tinogasta and at Mazan 38
  La Rioja, tin in 36
  Mazan, tin at 38
  Mines, mining, metallurgy, and mining laws of 38
  Salta, Chicoana, mineral deposits at 37
  Salta, La Poma district, mineral deposits of the 37
  See also South America.
Arksut, *see* Greenland: Evigtok.
Arsenic:
  Action on chlorides of mercury 1465
  Association of tin with ..... 172, 180a, 225, 227, 573a, 1025(?), 1314
  Berglund on the qualitative separation of tin, antimony, and arsenic. 1447
  Bunsen on the separation of arsenic from antimony and tin 1459
  Capitaine on action of tin, arsenic, antimony, and sulphur on the chlorides of mercury 1465
  Charleton on 1310
  Clarke on separating tin from arsenic, antimony, and molybdenum .. 1467
  Cornwall 1617
  de Koninch and Lecrenier on the qualitative separation of gold and platinum from arsenic, antimony, and tin 1474
  Dewey on Clarke's method of separating tin from arsenic and antimony 1477
  Eisner on separation from tin 1485
  Eisner on the separation of gold and platinum from tin and arsenic. 1486
  Headden on compounds of, in an old Cornwall furnace 1617
  Rawson on qualitative separation of arsenic, antimony, and tin 1553
  Rose on the quantitative determination of tin, arsenic, and antimony. 1559
  Separation from gold, platinum, and tin 1486
  Separation from gold, platinum, tin, and antimony 1474
  Separation from tin 1485
  Separation from tin and antimony 1447, 1459, 1477, 1553, 1559
  Separation from tin, antimony, and molybdenum 1467
Arsenical pyrites, *see* Association of tin with.

Association of tin with—Continued. Reference Number
Arsenopyrite, *see* also Arsenic....180a, 235a, 498, 523, 542, 573a, 586, 651, 726b, 792, 797, 816, 817, 872, 1009, 1034, 1155, 1183, 1183b, 1240, 1247, 1294
Augite 230
Autunite 999
Axinite 726b, 1009, 1024, 1314
Barite 180a, 523, 999, 1038, 1040, 1294
Barium sulphate, *see* Barite.
Beryl 227, 797, 817, 997, 1024, 1155
Beryllium in mineral waters..... 524
Biotite 1050
Bismuth..3b, 172, 180a, 225, 227, 235a, 573a, 797, 881, 898, 938, 1095, 1148, 1163, 1294
Bismuthinite 816
Blende 586, 1183b
Boron 726b, 1314
Cadmium 270
Calcium phosphate 523
Carbonates 1294
Cerium in mineral waters..... 524
Chalcedony 797
Chalcocite 573a
Chalcopyrite.....180a, 573a, 797, 816, 905, 1009, 1041, 1155, 1183
Chlorine 1327
Chlorite.....180a, 380, 904, 905, 1155
Cinnabar 3b, 259a
Cobalt in mineral waters..... 524
Cobaltite 1186b
Columbite 227, 523, 859, 996, 1009, 1010, 1015
Columbium minerals 1258
Copper.....3, 172, 188, 225, 227, 235a, 259a, 388, 410, 523, 586, 726a, 792, 881, 898, 938, 1119, 1168a, 1183, 1183b
Copper carbonate..... 792
Copper oxide 523
Copper pyrites.....3b, 380, 428, 542, 604, 817, 1183b
Copper sulphides 155, 1034
Copper sulphuret 792
Corundum 3d, 1052
Cryolite 586
Cupriferous quartz..... 1148
Cuprite 573a
Cuprocassiterite 1024
Cuproscheelite 1186b
Diamonds 817
Diopside 1148

Association of tin with—Continued. Reference Number

Durangite 227, 751, 753, 774
Earthy matter 164
Emerald 498, 797
Epidote 1148
Euxenite 3b, 3d, 1048, 1054
Feldspar 498, 586, 681
Fergusonite 1048, 1054
Fluorine 1314
Fluorite....8, 17, 227, 235a, 380, 523, 542, 573a, 586, 651, 654, 681, 726a, 726b, 797, 817, 927, 1009, 1155, 1168a, 1183, 1183b, 1294, 1314
Fluorspar, *see* Fluorite.
Gadolinite 587, 591
Galena, *see* also Lead....428, 498, 542, 573a, 586, 604, 629, 797, 816, 905, 999, 1038, 1119, 1148, 1155, 1163, 1183, 1183b, 1636
Garnet.....3b, 8, 17, 34, 207, 580(?), 859, 1148, 1168a, 1258, 1267
Gem minerals (in general).....256, 259, 817, 927
Gilbertite 498
Glycium (beryllium) in mineral waters..... 524
Gold..3b, 8, 17, 34, 40, 41, 50, 172, 180a, 188, 235a, 259a, 369, 395, 428, 586b, 599, 600, 601, 602, 604, 607, 797, 804, 831, 891, 1138, 1139, 1148, 1155, 1168a, 1327, 1444
Graphite.....905, 999, 1024
Hematite, *see* also Specularite....428, 604, 613, 627, 628, 681, 751, 753, 1168a, 1635
Heterosite 1024
Hornblende 1024, 1168a
Hübnerite 227
Ilmenite.....3d, 17, 256, 257, 428, 604, 673, 699, 856, 859, 927, 999
Indium 270
Iron.....5, 225, 573a, 586, 682, 1025(?), 1314
Iron arsenate 523
Iron oxide 164, 180a, 258, 380
Iron pyrites, *see* Pyrite and pyrrhotite.
Iron sulphides, *see* also Pyrite.....155, 180a
Kaolin.....380(?), 739, 1137
Lead, *see* also Galena....40, 180, 227, 229, 428, 602, 938(?), 1025(?), 1451
Lead carbonate 627
Lead sulphides 155
Lepidolite.....227, 593, 1009, 1314
Lime 258
Limonite 8, 17, 34, 227, 610, 613, 615, 621, 627, 643, 1040
Lithia mica .....542, 554, 573a, 1258(?)
Magnetite.....8, 17, 34, 180a, 227, 428, 604, 859, 955, 1052
Malachite 542
Manganese oxides, *see* Pyrolusite 258, 428, 604

Association of tin with—Continued. Reference Number
Manganite 227
Margarite 3b
Mica....245, 350, 380, 498, 505, 542, 554, 573a, 651, 654, 797, 817, 1016, 1137, 1181, 1183, 1238, 1240, 1258(?), 1263
Mispickel, *see* Arsenopyrite.
Molybdenite....227, 235a, 428, 523, 530, 573a, 580(?), 586, 604, 797, 927, 1024, 1147, 1148, 1183, 1183b
Molybdenum 1314
Molybdenum in mineral waters..... 524
Monazite....3b, 3d, 227, 673, 699, 797, 804, 856, 861a, 891, 903, 1048, 1052, 1054, 1078a, 1158
Montebrasite 496
Muscovite.....245, 498, 505, 1238 (plumose), 1258
Nickel in mineral waters..... 524
Niobic oxide, *see* Columbium.
Niobium, *see* Columbium.
Orthoclase 573a
Other minerals....29b, 252, 255, 305, 405, 433, 452, 509, 538, 642, 714, 791, 792, 797, 820, 936, 976, 992, 995, 996, 1000, 1017, 1083, 1184a, 1245, 1268, 1311, 1313, 1598
Phlogopite 498
Phosphorus 1314
Plagioclase feldspar..... 245
Platinum.....804, 831, 891, 1327
Pyrite....3b, 8, 17, 34, 158, 172, 180a, 227, 230, 235a, 428, 498, 573a, 604, 629, 681, 797, 816, 872, 1009, 1040, 1119, 1148, 1155, 1157, 1158, 1163, 1168a, 1183
See also Iron sulphides.
Pyrolusite, *see* also Manganese oxides.....227, 511
Quartz....3b, 3d, 180a, 207, 227, 230, 234a, 350, 380, 498, 505, 542, 573a, 586, 651, 654, 681, 726a, 797, 859, 870, 904, 1073, 1137, 1148, 1156, 1158, 1240, 1258, 1294, 1314
Rutile.....230, 257, 554, 1639
Sapphire.....259, 817, 1143
Scheelite.....3b, 227, 1186b, 1250
Siderite 180a, 227, 259a, 586
Sillimanite 1250
Silver....144, 145, 152, 155, 164, 166, 171, 172, 180a, 184, 225, 235a, 938(?), 1148, 1168a, 1294
Silver ores, *see* Silver.
Silver sulphides, *see* Silver.
"Sparry iron," *see* Siderite.
Specularite, *see* also Hematite.....530, 1183b
Sphalerite.....155, 180a, 229, 498, 816, 870, 905, 1024, 1040, 1086, 1155
Spodumene.....997, 1009, 1148

Association of tin with—Continued. Reference Number
Stannite 182
Stibiotantalite 1267
Stibnite 1182b
Sulphides 166, 182 1294
Tantalic oxide 258
Tantalite ..... 580(?), 586, 976, 993, 996, 1009, 1010, 1015, 1017
Tantalum 1208, 1258
Tantalum in mineral waters 524
Titanite 34, 230, 1257
Titanium, *see* also Rutile and titanite 682
Titanium in mineral waters 524
Topaz 235a, 259, 498, 542, 573a, 751, 753, 767, 797, 817, 1009, 1010, 1073, 1143, 1148, 1149, 1168a, 1172, 1181, 1267, 1294, 1337
Tourmaline 3b, 172, 180a, 207, 227, 235a, 350, 380, 385, 498, 505, 587, 591, 649, 681, 726b, 750, 792, 797, 811, 817, 859, 1010, 1034, 1041, 1137, 1155, 1156, 1158, 1168a, 1183, 1183b, 1186b, 1238, 1257, 1258, 1263, 1267, 1294, 1314, 1341
Tremolite 726a
Triphyllite 1024
Tripolite 1024
Tungsten 797, 898, 938, 1016, 1095, 1148, 1168a, 1314
See also Hübnerite, scheelite, and wolframite.
Tungsten in mineral waters 524
Uranium ..... 518(?)
Uranium phosphate 523
Vesuvianite 1148
White mica 797
Wolfram, *see* Wolframite.
Wolframite 3b, 64, 158, 188, 227, 235a, 333, 428, 511, 523, 542, 573a, 604, 682, 753, 792, 797, 811, 816, 817, 927, 943, 1009, 1010, 1015, 1024, 1034, 1078a, 1155, 1172, 1183b, 1186b, 1238, 1240, 1250, 1258, 1294, 1662, 1664
Wollastonite 1148
Wurtzite 1636
Xenotime 699
Yttrium in mineral waters 524
Zinc, *see* also Sphalerite ..... 225, 227, 602(?), 1025(?)
Zinc blende, *see* Sphalerite.
Zinc sulphides, *see* Sphalerite.
Zinnwaldite 573a
Zircon 257, 259, 586, 699, 817, 856, 1267
Zircon in mineral waters 524
Assyria, bronze articles in 1278
Audibert, E. 497
Aughey, Samuel 1274

Reference Number

Augite, *see* Association of tin with.
Australasia:
Coghlan on a statistical account of....1677, 1678, 1679
Coghlan on tin in the seven colonies of.... 48
Meunier on tin deposits of.... 53
See also Australia.
Australia, tin in....1223, 1287, 1289, 1298
Beck on tin deposits in.... 1299
Benedict on correspondence of tin bearing granite in, to that of Cornwall.... 47
Coghlan on tin in.... 1077
E———— on tin production, 1874–1875.... 49
Earl of Mount Edgcumbe on tin produced in 1883.... 1681
English on Australian and Tasmanian tin.... 50
Fawns on tin deposits of.... 1320
Fuchs and de Launay on tin deposits of.... 1323
Gregory on tin in.... 1092
Henwood on association of tin with gold and platinum in.... 1327
Johnson on tin in.... 51
de Lapparent on tin in.... 1335
de Launay (Fuchs and) on tin in.... 1323
Lock on tin deposits of.... 1338
Louis on tin deposits of.... 1340
Louis (Phillips and) on tin deposits of.... 1350
Mance on tin mining in Eastern States during 1905.... 52
Newland on tin in.... 1347
Newland on tin production in 1903.... 54
Newton on the metalliferous minerals of, including tin.... 55
Phillips and Louis on tin deposits of.... 1350
Plummer on tin deposits of.... 56
Plummer on tin production in 1904 and 1905.... 1698
Reyer on tin in.... 57
Robertson on bismuth and tin in.... 58
Stephen on tin production, 1877–1878.... 59
Thibault on metallurgy of tin in.... 1578
Trasenster on statistics of tin in, 1879–1881.... 1700
Tregay on tin in.... 60
Vale on tin in.... 61
Weeks on tin in.... 1372
Wolff on tin in.... 62
Woods on tin in.... 63
See also Australasia, New South Wales, Northern Territory, Queensland, South Australia, Tasmania, Victoria, and Western Australia.

Austria: Reference Number
Charleton on tin in ... 1310
D'Achiardi on tin deposits of ... 1313
Groddeck on tin in ... 549
Jars on tin in ... 416
Newland on tin in ... 1347
Newland on tin production of ... 70
Phillips and Louis on tin in ... 1350
Plants for recovery of scrap tin in ... 1438
Schultz on tin in ... 573
See also Bohemia.
Autunite, *see* Association of tin with.
Avicaya mine, *see* Bolivia.
Axinite, *see* Association of tin with.
Ayer Dangsang, *see* Malay Peninsula.
Ayer Panas, *see* Malay Peninsula.
Aztecs, tin used for coins by ... 1374

B

Babbitt metal, Meade on composition, uses, and analysis of alloys of ... 1531a
Babington, Arthur ... 886
Badger mines, *see* Tasmania.
Badjerican mine, *see* New South Wales.
Baikal region, *see* Siberia.
Bailey, Gilbert E., and Riotte, E. N. ... 988
Bain, W. H. ... 887
Baja California, *see* Mexico.
Baldauf, Martin ... 331
Bald Nob, *see* New South Wales.
Balfour, John F. ... 677
Ball, Lionel C. ... 331a, 331b, 331c, 888, 889, 890, 891, 891a, 891b
Ball, S. Mays ... 239a
Ball, V. ... 589, 590
Ballesterosite, Schulz and Paillette on, in Spain ... 1043
Balling, Carl ... 1443
Ballivián, M. V., and Saavedra, Bautista ... 150
Bandon, *see* Siam.
Banghi, *see* French Congo, Ubanghi.
Bangtaphan, Langsuan, *see* Siam.
Banka, tin in ... 1286, 1289
Akkeringa on tin in the Blinjoe district ... 73
Beck on tin deposits of ... 82
Benedict on tin deposits of ... 83, 1301
Blinjoe district, tin in ... 73
Boers on use of power machinery in working tin ground in ... 84

Banka—Continued. Reference Number
Bredemeyer on tin mining in ... 85
Cordes on tin in the Koba district ... 87
Cordes on tin in the Pangkal-Pinang district ... 86
Cretier on tin near Soengei Liat in the district of Muntok ... 88
Croockewit on tin in ... 89, 1473
Daubrée on tin in Germany ... 1314
Davies on alluvial mining in ... 1317
Diest on tin in ... 90, 94, 1478
Diest on tin in the Merawang district ... 92
Diest on tin in the Sambong-Giri ... 93
Diest on tin in the Soengei Liat district ... 91
Dijk on tin in ... 95, 96
Dijk on tin smelting in ... 1480
Djeboes district, tin in ... 98
Doorman on tin in the Dutch East Indies ... 286a
Doren on tin in ... 97
Earl of Mount Edgcumbe on tin produced in 1883 ... 1681
Everwijn on tin in the Djeboes district ... 98
Fawns on tin in ... 1320
Fraenkel on tin in ... 99
Fuchs and de Launay on tin in ... 1323
Godefroy on tin in ... 100
Groot on tin in ... 101
Henwood on association of tin with gold in ... 1327
Hooze on tin in ... 102
Horsfield on a mineralogical description of ... 103
Huguenin on tin in the Toboali district ... 104
de Jongh on tin in ... 108
de Jongh on tin in the Merawang district ... 106
de Jongh on tin in the Soengei Liat, Pangkal-Pinang, and Merawang districts ... 105, 107
Koba district, tin in ... 87
Lange on tin in ... 109
de Launay (Fuchs and) on tin in ... 1323
Menten on tin in ... 110
Merawang district, tin in ... 92, 105, 106, 107
Mulder on analyses of tin from ... 1538
Muntok district, tin near Soengei Liat ... 88
Oudemans on tin in ... 111
Pangkal-Pinang district, tin in ... 86, 105, 107, 115
Posewitz on tin in ... 112
Raffles on history of production, prices, placers, distribution, and market conditions of tin in ... 113
Renaud on tin in ... 116
Renaud on tin in the Pangkal-Pinang district ... 115
Renaud on tin in the Soengeiselan district ... 114

Banka—Continued. Reference Number
Reyer on tin in ... 1354
Reyer on tin mining in, writers on, and structure of the island ... 117
Rolker on tin in ... 719
Sambong Giri, tin in ... 93
Schuurman on history of tin mining in ... 1415
Smyth on tin in ... 1362
Soengei Liat district, tin in ... 88, 91, 105, 107
Soengeiselan district, tin in ... 114
Toboali district, tin in ... 104
Trasenster on statistics of tin in, 1879–1891 ... 1700
Van der Wyck on tin in ... 118
Verbeek on occurrence of tin in ... 136
Vlaanderen on tin in ... 120
Weeks on tin in ... 1372
See also East Indies.
Bannister, C. O. ... 1444
Bapst, Germain ... 1375, 1376
Barba, Alvaro Alonso ... 151
Barcena, Mariano ... 761
Barite, *see* Association of tin with.
Barjac, *see* France, Lozére.
Barnett, A. K. ... 332
Barrat, Maurice ... 272
Barren Waters, *see* Queensland.
Barrier Bischoff mine, *see* New South Wales.
Barrier Ranges field, *see* New South Wales.
Barriga, Manuel Diaz ... 762
Barrosa Cota mine, *see* Bolivia.
Barrow, George ... 333
Bartlett, Thomas ... 334
Bastar, *see* India.
Batavia, *see* Java.
Batten, John, Jr. ... 1377
Bauchi, *see* Nigeria.
Baudot, F. ... 498, 1378
Bauer, George ... 1277
Bauer, Max ... 1591
Bautshi tin fields, *see* Nigeria.
Bawden, S. ... 335
Bear Gulch district, *see* South Dakota.
Beaumont, Élie de (Dufrénoy, P. A. and) ... 378
Beales, R. L. ... 13
Béchamp, A., and Saintpierre, C. ... 1445
Becher, H. M. ... 678
Beck, Richard ... 1, 82, 529, 530, 531, 1299, 1300
Becke, F. ... 1592

Reference Number

Beco, Jean, and Thonard, Léon 612
Beechworth, *see* Victoria.
Beenah, *see* Victoria: Gippsland.
Beer, Adolph 806
Bell, James M. 852
Bell, R. N. 16
Bell, Robert M. 14, 15
Bell Mount, *see* Tasmania.
Bendemeer, *see* New South Wales.
Benedict, William de L. 5, 47, 83, 152, 212, 213, 240, 281, 336, 679, 763, 807, 989, 990, 1074, 1200, 1239, 1275, 1301
Bengal, *see* India.
Ben Lomond, *see* Tasmania.
Bennetts, Geo. 337
Bennetts, Samuel 338
Benoue, *see* Nigeria, Benue.
Benst, von 532
Bentong, *see* Malay Peninsula, Telom.
Benue River, *see* Nigeria.
Berenguela, *see* Bolivia.
Bergeat, Alfred 613
Bergemann, C. 764, 1446
Berger, J. F. 339
Berggiesshübel, *see* Saxony.
Berglund, Emil 1447
Bergman 1302
Bergse process for recovering tin from scrap 1442
Bernhardi 1593
Berthelot, P. 1379, 1448
Berthier, P. 1449, 1450
Berwick, *see* Victoria.
Beryl, *see* Association of tin with.
Berzélius 1303
Bettany, G. 1304
Bettel, W. 1450a
Betts, A(nson) G. 225, 1451
Bible 1380
Bibliographies:
  Benedict on an epitome of the reports upon the San Jacinto, California, tin mines 212
  Clarke on "The data of geochemistry" 1311
  Fawns on 1320
  Fay (13 articles on Alaska) 25
  Fuchs and de Launay on Bolivia, etc. 159
  Hess and Graton on occurrences of tin 1329

Bibliographies—Continued. Reference Number
Oldham on papers and reports on tin and other ores in Tenasserim, Burmah 198
Reyer on observers and writers on geology of Banka and Billiton... 117
Stelzner on Bolivia..... 183
Ward on North Dundas field, Tasmania.....1158a
Watson on mineral resources of Virginia..... 1246
Big Horn country, *see* Wyoming.
Big Prickly Pear Creek, *see* Montana.
Bilin, *see* Bohemia.
Billings, G. H..... 1452
Billiton, tin in.....77, 79, 126a
Akkringa (Akkeringa), on tin in..... 121
Beck on tin deposits of..... 82
Benedict on tin deposits of.....83, 1301
Boeding district, tin in..... 123
Cretier on tin in.....127, 283
Diest on tin in..... 128
Dindang district, tin in..... 123
Doorman on tin in Dutch East Indies..... 286a
Earl of Mount Edgcumbe on tin produced in 1883..... 1681
Fawns on tin in..... 1320
Ferrier on tin in..... 129
Fuchs and de Launay on tin in..... 1323
Groot on tin in.....130, 131, 132
Landon (Maier and) on tin in..... 133
de Launay (Fuchs and) on tin in..... 1323
Maier and Landon on tin in..... 133
Mangar district, tin in..... 123
Posewitz on discovery of tin in, geology of, occurrence and mining of tin in, and production of tin in the island of..... 134
Rant on tin in Tadjouw Mountain..... 135
Reyer on tin in..... 1354
Reyer on tin mining in, writers on, and structure of the island..... 117
Rolker on tin in..... 719
Smyth on tin in..... 1362
Tadjouw Mountain, tin in..... 135
Tandjang-Padan district, tin in..... 123
Trasenster on statistics of tin in, 1879–1881..... 1700
Van der Wyck on tin in..... 118
Verbeek on occurrence of tin in..... 136
Weeks on tin in..... 1372
See also East Indies.
Binns, George J..... 853
Binoxide of tin, Wendt on occurrence with ores of silver near Potosi, Bolivia 184
Biotite, *see* Association of tin with.

Reference Number

Bischoff (Mount) tin mines, *see* Tasmania.
Bishop Creek, *see* California, Inyo County.
Bitter Root Mountains, *see* Montana.
Bitter Root Range, *see* Idaho.
Bismuth:
Alloys with zinc and tin..... 1587
Andrews on deposits at Kingsgate, New South Wales..... 797
Argentina, Salta..... 37
Association of tin with....3b, 172, 180a, 225, 227, 573a, 797, 881, 898, 938, 1095, 1148, 1163, 1294
Australia..... 58
Benedict on occurrence at Chorolque, Bolivia..... 152
Bohemia, Erzgebirge..... 578
Bolivia, Chorolque..... 152
Castro on working of, in Salta, Argentina..... 37
Charleton on..... 1310
Foullon on..... 1322
Menniche on separation of, from tin ores..... 1534
New South Wales..... 797
Queensland..... 881
Robertson on deposits of, in Australia..... 58
Saxony, Erzgebirge..... 578
Separation from tin..... 1534
Tasmania.....1079, 1095, 1148
Twelvetrees on deposits in Tasmania..... 1148
Viebig on deposits of, in the Erzgebirge of Germany..... 578
Bismuthinite, *see* Association of tin with.
Bitter Root Mountains, *see* Idaho and Montana.
Black, A..... 340
Black Hills, *see* South Dakota and Wyoming.
Black Umbelosi River, *see* Transvaal.
Blake, William P.....214, 341, 991, 992–997, 1201, 1202
Blanchard, Fréd.....614, 615, 616
Blanford, W. T. (Medlicott, H. B. and)..... 595
Blavier, Ed., and Lorieux, T..... 499
Blende, *see* Association of tin with.
Blewett, Jasper..... 959
Blinjoe district, *see* Banka.
Block tin:
Preparation of, in Cornwall and Devon..... 1576
Resulting from distillation of tin amalgam..... 1556
Blöde, Gottlob von..... 533
Bloomfield, *see* Queensland.
Blue Ridge, *see* Virginia.
Blue Tier, *see* Tasmania.
Boase, G. C., and Courtney, W. P..... 342

	Reference Number
Boase, Henry S.	343, 344
Bob Ingersoll claim, *see* South Dakota.	
Boceheggiano, *see* Italy, Tuscany.	
Bodenmais, *see* New South Wales, Silberberg.	
Bodmin Moor, *see* Cornwall.	
Boeding district, *see* Billiton.	
Boerhaave, H.	1305
Boers, R. J.	84
Bog, *see* Cornwall.	
Boggild, O. B.	581
Bohemia:	
Albertham, tin deposits of	1310
Beck on tin in Graupen	1300
Benst on tin in Schlaggenwald	532
Bilin, tin near	562
Carlsbad, tin mine near	64
Charleton on tin deposits of Abertham	1310
Cotta on tin in Graupen	65
Cotta on tin in Graupen and Poebel	540
Dalmer on the Altenberg-Graupen tin district	542
Daubrée on tin in	1314
Davies on tin deposits of	1317
Erzgebirge, discrimination of granites in	564
Origin of tin deposits of	575
Silver-bismuth deposits in	578
Fuchs and de Launay on tin in	66
Graham on tin in	1324
Groddeck on tin in Graupen and Schlaggenwald	549
Graupen, tin at	65, 67, 69, 540, 542, 549, 550, 562, 567, 1300
Graupen, Luxer vein at	573a
Hallwich on tin in Graupen	67, 550
Jars on tin in	416
Joachimsthal, tin mine at	573a
Jokèley on tin "im Leitmeritzer Kreise"	68
Karlsbad, geology of	564
de Lapparent on tin in	1335
Laube on tin at Graupen	69
de Launay (Fuchs and) on tin in	66
Neudeck, geology of	564
Nowicki on tin at Schlaggenwald and Schönefeld	71
Platten, tin in	567
Poebel, tin in	540
Reuss on tin near Teplitz, Bilin, and Graupen	562
Reyer on discrimination of granites in the Erzgebirge	564
Reyer on geology of Neudeck and Karlsbad	564
Reyer on tin in Graupen, Platten, and Schlaggenwald	567

Bohemia—Continued. Reference Number
Reyer on tin mining in....565, 566, 567
Rücker on tin in Schlaggenwald.... 568
Schlaggenwald, tin at....71, 72, 532, 549, 567, 568
Schönefeld, tin at.... 71
Singewald on tin deposits in the Erzgebirge.... 573a
Teplitz, tin near 562
Upper Graupen, tin at 67, 550
Vogelsang on mining and smelting of tin at Schlaggenwald.... 72
Woodward on tin ore specimens from.... 489a
See also Austria and Europe.
Bohne, E.... 1453
Bolivia, tin in....1284, 1286, 1287, 1290, 1292, 1294, 1298
Antequera tin mine.... 180a
Apacheta mine, tin in....143, 158
Araca, tin at.... 176
Arecayo mine, tin in.... 143
Arzruni on several minerals from.... 149
Avicaya mine 158, 180a
Ballivian and Saavedra on tin in.... 150
Barba on tin in.... 151
Barrosa Cota mine, tin in.... 180a
Beck on tin in.... 1299
Benedict on tin at Potosi and Chorolque.... 152
Berenguela, tin from.... 166
Berkey on microscopic sections of tin ores and rocks from....152a, 180a
Bradley on tin in.... 153
Cataracaqua lode, tin in.... 180a
Challa mine, tin in....143, 158
Chocaltaya mine, tin in....158, 160
Chorolque, tin at....152, 166, 173, 178, 179
Chualla Grande, tin mines at.... 180a
Cochabamba department, tin in.... 141
Colquiri, tin at.... 158
Concordia lode, tin in.... 180a
Conway on tin mines of Huaina Potosi.... 154
Coya lode, tin in.... 180a
D'Achiardi on tin in.... 1313
Davies on tin in.... 1317
Elisa lode, tin in.... 180a
Emmons on occurrence of tin in.... 155
Endter on tin mines of Llallagua, near Oruro.... 155a
Everding on tin in.... 155b
Exportation of tin to United States discussed.... 139
Fawns on tin in....156, 1320
Forbes on occurrence and kinds of tin ores in.... 157
Foullon on tin in.... 1322

Bolivia—Continued. Reference Number
Frenzel on cylindrite from 1611
Frochot on tin in 158
Fuchs and de Launay on tin in 159, 1323
Gallofa lode, tin in 180a
Garrison on tin in 1207
Gautier on deposition of tin near Chorolque 160
Gmehling on metallurgy of tin in 1497
Harrison on tin in 161
Huaina Potosi, *see* Juaina Potosi.
Huanuni, *see* Juanuni.
Ichoca, tin at 176
Juaina Potosi, tin mines of 154, 158, 176
Juanuni district, tin in 141a, 143, 148c, 158, 166, 172, 173, 180
La Blanca, tin deposits of 146
La Bolivinia mine, tin in 180a
LaPaz department, tin in 141, 154, 158, 166
de Launay (Fuchs and) on tin in 159, 1323
La Unificada mine, tin in 180a
Light on tin deposits of 161a
Llallagua, near Oruro, tin mines of 155a
Llallagua vein, tin in 180a
Lock on tin in 1338
Louis on tin in 1340
Louis (Phillips and) on tin in 1350
Minchin on tin in 163, 164, 165, 166, 168, 169, 1346
Minchin on mines, ores, mining, production, and transportation of tin in 162, 167
Milluni mine, tin in 158, 176
Mining and railway development in 147
Monte Blanco mine 180a
Morococala tin mines 180a
Mount Poscovi, tin on 158
Negro Pabellon, tin at 180a
Newland on tin in 170, 1347
Ochsenius on tin in 171
Olaechea on tin in 171a
Oruro, tin at 137, 155a, 162, 164, 166, 170, 1641
Oruro department, tin in 137, 141, 143, 145, 158, 162, 164, 166, 170
Pasley on tin mines in the East Cordilleras 172
Pearce on tin in 1630
Peña on tin deposits of 172a
Penberthy on tin in 174, 467
Penberthy on tin mines and transportation problems in 173
Penfield on tin in 1631
Phillips and Louis on tin in 1350
Poopo Lake, tin near 162

Bolivia—Continued. Reference Number
Potosi, tin at....152, 164, 166, 173, 1641
Potosi department, tin in....141, 144, 152, 154, 164, 166, 173, 184
Pozoconi mountain, tin on.... 143
Preumont on tin in.... 176
Preumont on tin mining and transportation problems in.... 175
Prices of tin in, affected by quotations on product of Straits Settlements.... 1675
Prior on teallite in.... 1636
Punnett on tin deposits of.... 177
Quimsa Cruz, tin at.... 176
Quinsachata, tin in.... 146
Railway and mining development in.... 147
Roberts on geology of country near Chorolque, and on the tin mines and alluvial deposits.... 179
Roberts on tin in the Chorolque district.... 178
Rolker on tin in.... 1357
Romaña on tin in.... 180
Rumbold on origin of tin deposits in.... 180a
Saavedra (Ballivian and) on tin in.... 150
San Jose, tin deposits of.... 146
San Jose lode, tin in.... 180a
San Roque mine, tin in.... 180a
San Salvadora lode, tin in.... 180a
Santa Vela Cruz, tin at.... 176
Spencer on stannite from Oruro, Potosi, and Tatasi.... 1641
Steinman on the geology of the tin deposits of.... 181
Stelzner on occurrence of tin in....182, 183
Stelzner on franckeite from.... 1642
Tajo-polo, tin at.... 184
Tatasi, stannite from.... 1641
Totoral mine.... 180a
Tres Cruces, tin in the Sayaquiri vein in the mountains of.... 158
Tupiza, tin mine 67 miles south of.... 144
Uncia, production and improvements in tin mining.... 148c
Uncia, tin at....173, 180a
Veta Estaño, tin at.... 184
Wendt on tin in Potosi district.... 184
See also South America.
Bombay, *see* India.
Bonnard, A. H....345, 534
Bonwick, James.... 1075
Borax, Hennecke on occurrence in Persia.... 864
Borgström, L. H.... 1594
Borlase, Wm. Copeland....346, 1028, 1381, 1382, 1383
Borlase, Wm. Copeland, and Rosewarne, H.... 347

Reference Number

Borneo:
Everwijn on tin in Sukadana and Matan ... 291
Everwyn on tin in Kandawangan ... 288
Everwyn on tin in Matan ... 287, 291
Kandawangan, tin in ... 288
Kinebetungen River, tin from ... 307
Matam (Matan), tin in ... 287, 291
Posewitz on tin in ... 301, 302
Sukadana, tin in ... 287, 291
Tenison-Woods on tin from the Kinebetungen River ... 307
See also East Indies.
Boron, Berthelot on the action of oxygen on the compounds of tin, silicon, and boron ... 1448
See Association of tin with.
Botallack, *see* England.
Boucard, A. ... 1454, 1455
Bourgeois, Léon ... 1595
Bourke County, *see* New South Wales.
Bouse, Johno ... 646
Boven Banjoe field, *see* Sumatra, Palembang.
Braché, J. ... 1224
Brackenbury, C. ... 1455a
Bradley, D. H., Jr. ... 153
Brandenburg, H., Weyland A., and Kempen, A. R. ... 1456
Branner, John C., and Newsom, John F. ... 1306
Branxholm, *see* Tasmania.
Braun, Max ... 617
Brazil, source of tin used by ancients ... 1405
Breage, *see* Cornwall.
Bredemeyer, W. ... 85
Breidenbach, Th. ... 873
Breitenbrun, *see* Germany.
Breithaupt, A. ... 535
Bretherton, H. G. ... 765
Bridgetown, *see* Western Australia.
Bright, *see* Victoria.
Briseis mine, *see* Tasmania.
British Columbia, Brock on tin near Long Lake ... 226
Ingalls on tin from the Payne mill, near Sandon, Slocan district ... 229
Ingalls, Argall, and Gardé on zinc from, containing tin ... 229
Long Lake, tin near ... 226
Slocan district, tin from the Payne mill, near Sandon ... 229
Britain:
Origin of name ... 1389
Phœnician tin trade with ... 1389, 1400, 1414, 1418
Smirke on tin trade between Alexandria and ... 1417
Source of tin used by ancients ... 1405

Reference Number

Brittany, *see* France.
Broad Arrow mine, *see* Alabama.
Brock, R. W. 226
Brögger, W. C. 1596
Brögger, W. C. (Kjerulf, Th., and) 826
Broken Head, *see* New South Wales.
Broken Hill lode, *see* New South Wales.
Bromley, A. H. 766
Bronzes, ductilities of the various bronzes compared 1433
Brookite, Daubrée on artificial production of 1601
Brooks, A. H. 17, 18
Brooks, Cecil J. 1457
Brookstead tin field, *see* Tasmania.
Brothers' Home mine, *see* Tasmania.
Brown, A. Selwyn 1307, 1308
Brown, Gilmour E. 153a
Brown, H. Y. L. 973, 974
Brown, W. G. 1240
Browne, Frank 1458
Brunnich, Morten Thrane 348
Bruseh, *see* Malay Peninsula.
Bruthen, *see* Victoria.
Buck Creek, *see* Alaska.
Buddle (Williams) described, etc. 1668
Buddling of tin ore in Cornwall 1654, 1656
Buhner Creek, *see* Alaska.
Bukit, *see* Malay Peninsula, Telom.
Buller, John 349
Bunde, *see* Malay Peninsula.
Bungo, *see* Japan.
Bunsen, R. 1459
Bunter pebble bed, cassiterite in, in west of England 468
Burmah, tin in 188, 190, 588, 1290
  Amherst, tin at 597
  Fawns on tin in 1320
  Foss on tin and gold in Lower Burmah 188
  Fryar on tin in 189
  Grundy on tin in 190
  Helfer on tin and iron in Tenasserim district 191
  Henzai, tin at 188
  Holland on tin in Tenasserim district 192
  Hughes on tin in the Mergui district 193, 194
  King on tin in the Tenasserim district 195
  Lemon and Tremenheere on tin in Mergui and Tenasserim 196
  Lock on tin in Mergui and Tenasserim 197
  Maliwan, tin in 185, 187, 197, 201, 202, 205, 207, 590

Burmah—Continued. Reference Number
Medlicott on tin in Tenasserim ... 595
Mergui district, mines in listed ... 193
Mergui district, tin in ... 185, 188, 193, 194, 196, 197, 203, 204, 206, 597, 739
Oldham on coal fields and tinstone deposits in Tenasserim ... 199
Oldham on tin in the Tenasserim district ... 198, 199
Reyer on tin in ... 303, 1354
Royle on tin in Tenasserim ... 200
Rudra on tin at Amherst, Tavoy, and Mergui ... 597
Snow on tin at Maliwun ... 201
Tavoy, tin at ... 597
Tenasserim district:
Coal in ... 199, 200
Iron in ... 191
Tin in ... 191, 192, 195, 196, 197, 198, 199, 200, 205, 589, 590, 595, 744
Chanda, tin from ... 720
Lake Loadut ... 200
Pakchan River ... 200, 202, 205
Tremenheere on tin in Tenasserim ... 739
Wray on tin in Malacca and Tenasserim ... 744
Theobald on the metalliferous resources of ... 202
Theobald on tin near the Pakchan River ... 202
Tremenheere on tin in the Mergui district ... 203, 204, 206
Tremenheere on tin in the Tenasserim provinces ... 205
Tremenheere (Lemon and) on tin in Mergui and Tenasserim ... 196
Warth on tin deposits of ... 207
See also Malay Peninsula and Asia.
Burnard, Robert ... 1384
Burnet County, *see* Texas.
Burra Burra district, *see* New South Wales.
Burrowa Creek, *see* Victoria.
Burrows, J. C. (Thomas, Wm., and) ... 475
Burthe, M. P. L. ... 500
Busanga mine, *see* Kongo, Katanga.
Bushveld, *see* Transvaal.
Business methods, Taylor on, in mines of Cornwall and Devon ... 1663
Buttgenbach, H. ... 273, 274, 275
Busz, K. ... 350

C

Cacária, *see* Mexico, Durango.
Cáceres, *see* Spain.
Cadiz, *see* Spain. (Gades in Latin.)
Cadmium, Wells on separation of copper from ... 1583
See Association of tin with.
Cahours, A. ... 1460
Cahours, A. (Jolyet, F., and) ... 1508

Reference Number

Cahours, A., and Demarçay, E.....1461, 1462
Cahours, A., and Riche, A.....1463, 1464
Caillaux, Alf..... 618
Cajatambo, *see* Peru.
Calcifer, *see* Queensland.
Calcining of tin ore:
Cornwall 1654
Erzgebirge of Saxony..... 1658
Phillips on improved furnace for..... 1661
Calcium phosphate, *see* Association of tin with.
Calderón, D. Salvador..... 1029
California, tin in.....1192, 1196, 1281
Benedict on tin in.....213, 1200, 1301
Benedict on the San Jacinto tin mines..... 212
Blake on tin in..... 1202
Blake on tin on Feather River, Plumas County.....214, 1201
Day on tin in.....1203a, 1319
Emmens on tin in..... 1205
Fairbanks on geology of Temescal district, and the occurrence of the system of tin veins.....215, 216
Garrison on the Temescal tin mine.....217, 1207
Hanks on tin in San Bernardino County..... 1394
Hanks on the Temescal mines..... 218
Inyo County, tin on Bishop Creek..... 211
Jackson on tin in..... 219
Kemp on tin in..... 1213
Knight on the Temescal mines (San Jacinto)..... 220
Los Angeles, tin, gold, and silver near..... 208
Ohly on tin at Temescal..... 1215
Plumas County, tin on middle fork of Feather River.....214, 1201
R———— on tin in..... 1218
Roessler on tin near San Jacinto..... 221
Rolker on tin in..... 1357
San Bernardino County, tin in..... 1394
San Jacinto mines, tin in.....210, 212, 220, 221
Temescal, tin at.....1207, 1215
Temescal district, tin in.....209, 215, 216, 217, 218, 220, 222, 223
West on the Temescal tin mines..... 222
Whitney on tin in the Temescal district..... 223
See also United States.
California Creek, *see* Queensland.
Calorla mine, *see* New South Wales.
Calvert, Albert F..... 1030
Calvi, *see* Italy, Tuscany, Monte Calvi.
Camborne, *see* Cornwall.
Cambrian pegmatitic granite, cassiterite in..... 1010

Reference Number

Cameron, Walter E. 892–896
Campagne, Emile Mathieu 1309
Campbell, Harry D. 1241
Campiglia, *see* Italy, Tuscany.
Campiglia Marittima, *see* Italy, Tuscany.
Campo Alle Buche, *see* Italy, Tuscany.
Canada:
  Betts on tin in refined lead 225
  Kemp on tin in 1213
  Wolf on tin in refined lead 231
  See also British Columbia, Greenland, Nova Scotia, Quebec, Yukon.
Canfieldite, Penfield on a new sulphostannate of silver from Bolivia 1631
Canned meats, effect of tin on 1290
Cao-Bang, *see* China, Yunnan.
Cape Colony:
  Cape Peninsula, tin deposits of 233a, 233b, 233c
  Griffiths on new method of concentrating alluvial tin at Kuils River, 234a
  Griffiths on tin in the Kuils River field 234
  Hazendal tin deposits 235a
  Hoogekrall tin deposits 235a
  Johnson on tin at Welbeloond and Langerwacht 2a
  Keyzer on tin between the Kuils River and Stellenbosch 235
  Kuils River tin field 3b, 233, 233a, 233c, 234, 234a, 235, 235a, 1047
  Langerwacht tin deposit 2a, 235a
  Papkuilsfontein tin deposits 235a
  Rumbold on Kuils River tin deposits 3b
  Stokes on tin in 730
  Wagner on the tin deposits of 235a
  Welbeloond tin deposit 2a, 235a
  See also Africa and South Africa.
Cape Mountain, *see* Alaska.
Cape Nome, *see* Alaska.
Cape Prince of Wales, *see* Alaska.
Capitaine, H. 1465
Capron Springs, *see* Virginia.
Caradon, *see* Cornwall.
Carbonates, *see* Association of tin with.
Carcanagues 1651
Carclaze mine, *see* Cornwall.
Card, George W. 808
Carew, Richard 351
Carlsbad, *see* Bohemia.
Carn Brea mine, *see* Cornwall.
Carne, J. E. 809
Carne, Joseph 352, 353, 354, 355, 356, 357
Carnon, *see* Cornwall.

Reference Number

Carolinas, Struthers and Pratt on tin in 1220
See North and South Carolina, and United States.
Caron, H. (Deville, Saint-Claire, H., and) 1605
Carpenter, F. R. 998–1001
Carpenter, F. R., and Headden, W. P. 1466
Cartagena, *see* Spain.
Carter, A. Cecil 960
Carthagene, *see* Spain.
Cassiterides:
Rhys on history of 1413
Smith on history of 1418
Cassiteris, Plinius on tin from island called 1408
Cassiterite:
Artificial production of 1311, 1602, 1610, 1648
Arzruni on cassiterite as a furnace product 1590
Borgström on cassiterite from Pitkäranta, Finland 1594
Bourgeois on occurrence and formation of 1595
Carne on pseudomorphs after feldspar and quartz 357
Chapman on pseudomorphs after feldspar twins 1597
Chemistry, *see* Chemistry of tin.
Clarke on artificial production of 1311
Crystallization, *see* Crystallization of tin.
Cornwall 1617, 1640
Dana on 1600
Daubrée on artificial production of 1602
Davey on pseudomorphs after feldspar in Huel Coates mine, St. Agnes, Cornwall 1603
Finland, Pitkäranta 1594, 1612
Fouqué and Lévy on artificial production of 1610
France 516
Furnace product 1590
Gadolin on cassiterite crystals from Pitkäranta, Finland 1612
Genth on pseudomorphs after hematite 771
Gregg and Lettsom on form, analyses, occurrence, and varieties of 1614
Headden on, in an old Cornwall furnace 1617
Irving on occurrence and association at Nigger Hill, Black Hills, South Dakota 1010
Kohlman on measurements of crystals of 1624
Lacroix on distorted crystals from France 516
Mexico, Durango 1635
Mineralogy, *see* Mineralogy of tin.
Molengraaff on distorted crystals from Swaziland 1052
Occurrence, *see* Occurrence of tin.
Origin, *see* Origin of tin.
Pearce on pseudomorphs of, after sulpho-stannites 1630
Petterd on varieties in Tasmania 1118, 1121

Cassiterite—Continued. Reference Number
Phillips on cleaving cassiterite crystals so that the angles may be measured 1634
Phillips on crystallization of.....1633, 1634
Phillips on pseudomorphs after orthoclase..... 1632
Pilz on cassiterite secondary after stannite.
Pirsson on hematite enclosing cassiterite at Durango, Mexico..... 1635
Pseudomorphs....357, 478, 479, 771, 1078a, 1149, 1597, 1603, 1616, 1630, 1632, 1638
Reid and Scrivenor on pseudomorphs after feldspar..... 1638
Replacing tourmaline which had replaced feldspar in Tasmania....1078a
Rosenbusch on association with rutile as rock making mineral in the granite of Greifenstein..... 1639
Solly on tin crystals in the various mines of Cornwall..... 1640
Swaziland 1052
Tasmania 1078a, 1118, 1121, 1149
Tweedy on pseudomorphs after feldspar.....478, 479
Twelvetrees and Petterd on feldspar and quartz replaced by, at Mt. Bischoff, Tasmania 1149
Vogt on the artificial production of..... 1648
Western Australia, Pilbarra (distorted crystals)..... 1649
Woolnough on distorted crystals from Pilbarra, Western Australia.. 1649
Castro, Mariano Salas..... 37
Cataracagua lode, *see* Bolivia.
Celebes:
Koperberg on tin in Menado..... 296
See also East Indies.
Cento Camerelle, *see* Italy, Tuscany.
Central Asia, *see* Asia.
Cerium, *see* Association of tin with.
Cerro de Iglesia de los Remedios, *see* Mexico, Durango.
Ceylon:
Coomaraswamy on tin from Niriella, near Ratnapura.....255, 256
Coomaraswamy and Parsons on tin at Niriella, Induwehena, near Dela, and in Kuruwita..... 257
Dela, tin near..... 257
Dunstan on tin at Niriella..... 258
Induwehena, tin at..... 257
Kuruwita, tin at 257
Niriella, near Ratnapura, tin from.....255, 256, 257, 258
Niriella (Palle Patuwa, Nowadun Korale, Sabaragamuwa), tin at... 256
Noragala, stream tin at..... 259
Parsons on tin at Noragala..... 259
Parsons (Coomaraswamy and) on tin in..... 257
Chaija, *see* Siam.
Chalcedony, *see* Association of tin with.
Chalcocite, *see* Association of tin with.

Reference Number

Chalcopyrite, *see* Association of tin with.
Chaldeans, Berthelot on metals and minerals used by..... 1379
Challa mine, *see* Bolivia.
Chance, H. M..... 1002
Chanda, *see* Burmah, Tennaserim.
Chandler, C. F..... 767
Changkat Pari, *see* Malay Peninsula.
Chanteloube, *see* France.
Chaplin, G. P..... 358
Chapman, E. J..... 1597
Charcoal crucibles, assays of tin in..... 1513
Charente, *see* France.
Charleton, Arthur G..... 1310
Charlon, E..... 619
Charpentier, J. F. W..... 536
Chasewater, *see* Cornwall.
Chauvenet, Regis.....1164a
Chaya, *see* Siam.
Chemistry, Boerhaave on history, theory, and practice of..... 1305
Chemistry of tin:
Allen on metastannic acid and stannic sulphate..... 1430
Analysis.....1446, 1515, 1531, 1538, 1539, 1583, 1616
See also Analyses of tin.
Béchamp and Saintpierre on separation of gold and platinum from tin and antimony..... 1445
Bergemann on analysis of tin from Xeres, Mexico..... 1446
Berglund on the qualitative separation of tin, antimony, and arsenic, 1447
Berthelot on the action of oxygen on the compounds of tin, silicon, and boron 1448
Boerhaave on 1305
Boucard on..... 1454
Boucard on separation of gold and platinum from tin and antimony, 1455
Brooks on the quantitative estimation of tin..... 1457
Bunsen on the separation of arsenic from antimony and tin..... 1459
Cahours on organic tin compounds..... 1460
Cahours and Demarçay on organic tin compounds.....1461, 1462
Cahours and Riche on organic tin compounds..... 1463, 1464
Capitaine on the action of tin, arsenic, antimony, and sulphur on the chlorides of mercury..... 1465
Clarke on the separation of tin from arsenic, antimony, and molybdenum .....1467 (*see* also 1477)
Collins on the solubility of cassiterite.....1469
Cramer on precipitation of silver out of tin..... 1472
de Koninch and Lecrenier on the qualitative separation of gold and platinum from arsenic, antimony, and tin..... 1474

Chemistry of tin—Continued. Reference Number
Delachanal and Mermet on a compound of tin, platinum, and oxygen. 1475
Dewey on Clarke's method of separating tin from arsenic and antimony 1477
Dykes on analyses of slags..... 1483
Elsner on separation of arsenic and tin..... 1485
Elsner on separation of gold and platinum from tin and arsenic.... 1486
Engel on the action of tin nitrate upon tin..... 1488
Engel on stannic acid..... 1487
Estimation.....1457, 1491, 1493, 1574, 1585
Feuchtwanger on..... 1321
Fraenkel and Fasal on estimation of tin in salts of tin..... 1493
Frangken on the determination of tin..... 1491
Gaultier de Claubry on..... 1494
Gay-Lussac on the separation of antimony and tin..... 1495
Gerardin on the bichloride of tin as a solvent..... 1496
Granger on a crystallized sulphophosphide of tin..... 1613
Greg and Lettsom on analyses of cassiterite..... 1614
Gregor on weathering of metallic tin to the chloride of tin..... 1498
Hayes on the action of metallic tin on solutions of muriate of tin... 1501
Headden on analyses of stannite and its alteration products..... 1616
Henz on separation of antimony and tin..... 1503
Jameson on..... 1621
Jolyet and Cahours on the physiologic action of stannethyl and stannmethyl 1508
Kenngott on the alkaline reactions of several minerals..... 1509
Kersten on tin at Altenberg and in Peru..... 1512
Klaproth on chemical examination of oxide and sulphuret of tin.... 1513
Lampadius on analyzing the minerals of tin..... 1515
Levol on the quantitative separation of tin and antimony..... 1519
Lewy on some new combinations of the perchloride of tin..... 1522
Lowig on new organic radicals containing tin..... 1528
Mallett on analysis of tin pyrites..... 1531
Mene on..... 1332
Mengin on the separation of tin and antimony in an alloy..... 1533
Menniche on recovering silver, lead, bismuth, tungsten, and copper from tin ores..... 1534
Moissenet on..... 1536
Moody on hydrolysis of salts of tin in presence of iodides and iodates. 1537
Mulder on analyses of Banka tin..... 1538
Muller on the analysis of tin ores..... 1539
Musculus on stannic hydrate..... 1540
Ordway on some soluble basic salts of tin..... 1543
Pearce on application of chemistry to dressing of tin ores..... 1546
Personne on the combinations of iodine and tin..... 1550
Plattner on alloys of lead with tin and antimony..... 1552

Chemistry of tin—Continued. Reference Number
Rawson on the qualitative separation of arsenic, antimony, and tin.. 1553
Rieffel on chemical combinations of copper and tin, and on their alloys 1557
Rose on the quantitative separation of tin, arsenic, and antimony... 1559
Rose on the separation of tin and antimony..... 1558
Salet on the spectrum of tin..... 1561
Sandall on preparing the protoxide of tin..... 1563
Scheurer-Kestner on the action of oxygen on the protochloride of tin and on the combination of tin with permanganate of potassium.. 1565
Scheurer-Kestner on the behavior of some chlorides of tin.....1564, 1565
Schunck, Smith, and Roscoe on manufacture of tin chloride compounds and stannate of soda in the South Lancashire district, England 1568
Separation....1445, 1447, 1455, 1459, 1467, 1472, 1474, 1477, 1485, 1486, 1495, 1503, 1519, 1533, 1534, 1553, 1558, 1559, 1572, 1575, 1581, 1585
Slagle on the double halides of tin with aniline and the toluidines.. 1569
Smith (J. L.) on the separation of tin and antimony..... 1572
Streng on a microscopical-chemical reaction for the testing of tin... 1574
Talbott on the quantitative separation of tin and tungsten..... 1575
Thomas on the action of the peroxide of nitrogen on the halogen salts of tin..... 1580
Vignon on the precipitation of tin from tin-chloride..... 1581
Vignon on the easy oxidation of the reduced metal.....1581, 1582
Wells on the analysis of tin ores..... 1583
Witmer on the electrolytic determination of tin and its separation from antimony..... 1585
See also Analyses of tin, metallurgy of tin, assays of tin, origin of tin.
See references Nos. 1428–1587.
Chesterfield, *see* Massachusetts.
Chicoana, *see* Argentina, Salta.
Chili, Foullon on tin in..... 1222
Götting on tin at Punitaqui..... 259a
Light on tin deposits of..... 161a
Möricke on tin at Punitaqui..... 260
See also South America.
Chillagoe, *see* Queensland.
China, tin in..... 1287
Beck on tin in..... 1299
Browne on tin in..... 1458
Collins on occurrence, mining, and metallurgy of tin, and the mining laws and customs in Yunnan..... 266a
D'Achiardi on tin in..... 1313
Fawns on tin in..... 1320
Gongong, tin near.....261 (*see* also 742)
Grosier on iron, lead, and tin in..... 267

China—Continued. Reference Number
Kuochinchang, tin in ... 262
de Lapparent on tin in ... 1335
Leclère on tin and copper in Yunnan ... 268
Mineral resources of ... 263
Pansner on tin in ... 269
Willis on tin deposits in Yün-nan ... 269a
Yunnan:
Tin deposits, mining laws, and customs in ... 266a
Tin in ... 262
Cao-Bang, in the north of Tonkin, tin near ... 265
Kotchiou, tin at ... 264
Kotiou, tin at ... 268
Lingngau-fu, tin in ... 263
Malaken, tin at ... 268
Tomuko, tin at ... 268
Tsementong, tin at ... 268
See also Indo-China and Asia.
China clay, Symons on production at Carclaze, Cornwall ... 463
Chin chin, *see* Malay Peninsula, Malacca.
Chinese method of smelting tin, *see* Smelting of tin.
Chlorine, *see* Association of tin with.
Chlorite, *see* Association of tin with.
Chocaltaya mine, *see* Bolivia.
Chorolque, *see* Bolivia.
Chota Nagpur, *see* India.
Christianshaabs, *see* Greenland.
Chromium, Moody on hydrolysis of salts of, in presence of iodides and iodates ... 1537
Chualla Grande, *see* Bolivia.
Church, A. H. ... 620
Cieux, *see* France.
Cinnabar, *see* Association of tin with.
Clarence district, *see* New South Wales.
Clark, Donald ... 1076, 1076a
Clarke, Frank W. ... 1311, 1467
Clarke, W. B. ... 810, 811, 812, 813, 814
Clay crucibles, behavior of tin in ... 1513
Claypole, E. W. ... 1003
Cleland, W. Lauder ... 897
Cleveland mine, *see* South Dakota, Black Hills.
Clifford, Hugh ... 680
Cligga Head, *see* Cornwall.
Clitters tin mine, *see* Cornwall.
Clough, C. T. (Flett, J. S., and) ... 955

Reference Number

Clotten, E. 898
Coal:
Burmah, Mergui 188
Burmah, Tenasserim 199
Clarke on coal in New South Wales 813
Foss on presence of, 28 miles from Mergui, Burmah 188
New South Wales 813
Oldham on coal and tin deposits of Tenasserim, Burmah 199
Queensland 877
Swaziland 1046
Tasmania 1079, 1144
Twelvetrees on deposits in Tasmania 1144
Western Australia 1272
Woodward on deposits in Western Australia 1272
Coapanga, *see* Mexico, Guerrero.
Cobalt, *see* Association of tin with.
Cobaltite, *see* Association of tin with.
Cochabamba, *see* Boliva.
Codrington, T. 359
Coghlan, T. A. 48, 815, 1077, 1677, 1678, 1679
Coinage (tribute) of tin:
Carew on, in England 351
Maclean on, in England 1404
Pearce on, in England 1407
Coins, tin:
Malay Peninsula, Pahang, ancient coin discovered in 736
Mexico, chisel-shaped money used in 769
Use by Aztecs 1374
Colenso, John W. 360
Cooks Kitchen, *see* Cornwall.
Cooktown, *see* Queensland.
Coolangatta (Currumbin-) Beach, *see* Queensland.
Collett, Octave J. A. 681
Collettes, *see* France, Allier.
Collier, Arthur J. 19, 20, 21, 22, 23, 1250
Collins, Henry F. 1468
Collins, J. H. 361, 362, 363, 364, 365, 366, 367, 368, 369, 768, 1385, 1469, 1470, 1598, 1652, 1680
Collins, W. F. 266a
Colorado, Emmons on tin at Leadville 270
Leadville, tin at 270
San Juan Mountains, tin in 271
Stevens on tin in the San Juan Mountains 271
See also United States.
Colquiri, *see* Bolivia.

Columbite: Reference Number
Dana on tin in ... 1600
Influence of, upon tin assaying ... 1466
See Association of tin with.
Columbium, *see* Association of tin with.
Combes, Charles ... 370
Commans, Robert E. ... 1653
Comstock, T. B. ... 1165–1168
Concentrating plant, South Dakota, Harney Peak ... 983
Concordia lode, *see* Bolivia.
Conder, Hartwell ... 816, 1078, 1078a
Coneto, *see* Mexico.
Congo, *see* Kongo.
Conrad mines, *see* New South Wales, Howell.
Conradite, Thibault on a new compound of stannic and ferric oxides from the Conrad mines, Howell, New South Wales ... 1644
Conway, Sir Martin ... 154
Coolbawn, *see* Ireland.
Coolgara district, *see* Queensland.
Coomaraswamy, Ananda K. ... 255, 256. *See* also 258 and 259
Coomaraswamy, A. K., and Parsons, James ... 257
Copper:
Alloys of, with tin ... 1433, 1504, 1557
Argentina, Salta ... 37
Associated with tin, *see* Association of tin with.
Ball on in Stanthorpe district, Queensland ... 889
Beck on occurrence at Schwarzenberg, Germany ... 530
Berzelius on occurrence of ... 1303
Billiton ... 126a
Boase on separation of copper and tin from ores in Cornwall ... 343
Bolivia ... 155, 172
Bouse on ores in Madagascar ... 646
Burmah ... 188
Buttgenbach on presence in Katanga ... 275
Campagne on mines of ... 1309
Castro on, in Salta, Argentina ... 37
China ... 268
Collins on copper mines of Cornwall and Devon ... 364
Collins on copper and other minerals of Cornwall ... 368
Cornwall ... 343, 364, 368, 378, 388, 412, 422a, 426, 455, 473, 481a, 1425, 1479, 1656
Devon ... 364, 1425
Dietzsch on treatment of tin-wolfram-copper ores in Cornwall ... 1479
Douglas on metallurgy of ... 1204
Dressing of ... 1425, 1654
Dufrénoy and Beaumont on copper in Cornwall ... 378
Emmons on occurrence in United States and genesis of minerals of ... 1206

Copper—Continued. Reference Number
England 457
Farrell on deposits of in Katanga..... 276
Ferguson on dressing of..... 1654
Finland 950, 953a
Foniakoff on deposits in Siberia..... 965
Fox on tin and copper veins in Cornwall..... 388
France, Vaulry..... 523
Great Britain 444
Greenland 580
Germany, Schwartzenberg..... 530
Hennecke on occurrence in Persia..... 864
Henwood on manipulation of, in central mining district of Cornwall. 1656
Hunt on copper production of Cornwall..... 412
India, Bengal 596
Ireland, Wicklow..... 603
Jackson on the copper mines of the Lake Superior region..... 653
Kinahan on tin in copper bearing veins in Wicklow, Ireland..... 603
Kongo..... 3
Kongo, Katanga.....275, 276
Lake Superior region..... 653
de Launay on occurrence in the French Kongo..... 3
Lington on the Dolcoath copper and tin mine..... 422a
MacAlister on productive ore ground at Camborne, Cornwall..... 426
Madagascar 646
Menniche on separation of, from tin ores..... 1534
Metallurgy.....343, 444, 1204, 1425, 1479
Mining of.....1425, 1656
Oates on copper and tin deposits of Bengal, India..... 596
Occurrence of..... 1303
Origin of minerals of..... 1206
Pearce on separation from tin ore..... 1547
Persia 864
Pilz on deposits in Cartagena, Spain..... 1040
Pryce on mining and metallurgy of in Great Britain..... 444
Queensland.....877, 881, 889, 932, 935
Rieffel on chemical combinations of tin and copper, and on their alloys 1557
Schoultz-Ascheraden on deposits in Finland..... 950
Sellheim on Herberton district, Queensland..... 932
Separation from cadmium..... 1583
Separation from tin ores.....1534, 1547
Siberia 965
Simmons on occurrence of ores in Cornwall..... 455
Skertchly on deposits in Queensland..... 935
Smelting of..... 1425
Smyth on occurrence in England..... 457

Copper—Continued. Reference Number
South Africa ... 3c
Spain, Cartagena ... 1040
Sulphides of, associated with tin in Bohemia ... 155
Tasmania ... 1072, 1079
Tasmania, condition of mines, 1904 ... 1072
Thomas on copper ores near Redruth, Cornwall ... 473
Trüstedt on copper ore deposits at Pitkäranta, Finland ... 953a
Tylor on earliest production of iron, copper, and tin ... 1420
United States ... 1206
Vivian on history of copper mining in Cornwall ... 481a
Voit on deposits of, in South Africa ... 3c
Wells on separation of cadmium from ... 1583
World statistics since 1890 ... 1694
Worth on mining, dressing, smelting, and sale of, in Devon and Cornwall (historical) ... 1425
Copper alloys:
Analyses of ... 1433
Heycock and Neville on copper and tin alloys ... 1504
Properties of the alloys of copper and tin ... 1433
Specific gravities of ... 1433
Stress tests of ... 1433
Copper carbonate, *see* Association of tin with.
Copper oxide, *see* Association of tin with.
Copper pyrite, *see* Association of tin with.
Copper sulphides, *see* Association of tin with.
Copper sulphuret, *see* Association of tin with.
Coquebert, Ch. ... 1031
Cordes, J. H. ... 86, 87
Cork, *see* Ireland.
Corner Inlet, *see* Victoria.
Cornish miners (tin):
Collins on ... 268
Henwood on character of, etc. ... 402
Leifchild on ... 422
Wait on habits, characteristics, and mining methods ... 482
Cornubian ... 681a
Cornwall, tin in ... 1294, 1298, 1298b
Adger on analysis of an anomalous specimen of stannite from ... 1588
Anonymous, *see* also W. K.
Argall on tin at Wheal Vor in Breage ... 330
Baldauf on Redruth, Dolcoath, and East Pool mines ... 331
Ball on comparison of mining and milling methods with those of Queensland ... 331a
Ball on tin mining and milling at Botallack, Wheal Bassett, South Crofty, and Porth Ledden ... 331b
Ball on mining methods in ... 331c

Cornwall—Continued. Reference Number

Barnett on elvan courses, greenstones, and sandstones of Cornwall, and their associated minerals.... 332
Barrow on high-level terraces of Bodmin Moor, and their relation to tin and wolfram deposits.... 333
Beaumont (Dufrénoy and) on tin in.... 378
Benedict on correspondence of tin bearing granite in Australia to that of.... 47
Benedict on tin in....336, 1301
Bennetts on tin in St. Agnes district.... 338
Berger on the physical structure and mines of.... 339
Bettel on wet and dry methods of assaying in....1450a
Black on Carclaze tin mine.... 340
Blake on the Dolcoath mine.... 341
Boase on tin in.... 344
Boase on tin of Botallack and Levant.... 343
Boase and Courtney on tin mining in.... 342
Bog tin deposit.... 402
Bonnard on tin in the Polgooth, Carclaze, and Pentowan mines.... 345
Borlase on antiquities of.... 1382
Borlase on history of tin trade in.... 1383
Borlase on tin in.... 346
Borlase and Rosewarne on tin in.... 347
Botallack, geology and tin of....331b, 343
Breage, tin in.... 420
Brunnich on tin in.... 348
Buller on tin at St. Just.... 349
Burnard on the antiquity of mining in.... 1384
Burrows (Thomas and) on the Dolcoath mine.... 475
Camborne, tin at 329g, 385, 411, 425, 426
Camborne to Chasewater, survey from.... 471
Caradon and Liskeard district, mining in.... 484
Carcanagues on dressing of tin ores in.... 1651
Carclaze tin mine....340, 345, 418, 463, 474
Carew on tin in.... 351
Carn Brea tin mine....329g, 380, 389, 474
Carn Brea Hill, section through.... 431
Carne on the relative age of the metalliferous veins of.... 353
Carne on tin in.... 357
Carne on tin at Drift Moor near Penzance.... 355
Carne on tin at St. Just.... 353
Carnon tin deposit.... 402
Chaplin on mine timbering, especially in the Dolcoath mine.... 358
Chasewater to Camborne, survey from.... 471
Clitters mine, treatment of tin-wolfram-copper ores at.... 1479
Cligga Head, tin lodes at.... 449
Codrington on tin in.... 359

Cornwall—Continued. Reference Number
Colenso on Happy Union mine at Pentuan..... 360
Collins on Cornish tinstones and tin capels..... 1598
Collins on Goonbarrow mine near St. Austell..... 363
Collins on history of tin production in..... 1385
Collins on origin and development of ore deposits in..... 367
Collins on stanniferous deer horns in..... 365
See also on this subject 372 and 726b.
Collins on tin in.....361, 364, 366, 368
Collins on tin production, 1201–1800..... 1680
Collins on use of impact screen at Wheal Kitty..... 1652
Combes on tin in..... 370
Cooks Kitchen, tin at..... 389
Cotta on tin in.....371, 1312
Couch on stanniferous deer horns in..... 372
Courtney (Boase and) on tin mining in..... 342
Dahlblom on tin in..... 373
Daubrée on tin in..... 1314
Davey on pseudomorphous tin oxide after feldspar in Huel Coates mine, St. Agnes..... 1603
Davies on phenomena of heaves and faults in mineral veins in..... 374
Davies on tin veins at St. Agnes.....374, 1603
Davy on tin in..... 375
Day on tin in..... 1318
Deer horns (stanniferous).....365, 372, 726b
De La Beche on tin in..... 376
Dew on tin in..... 376a
Dietzsch on treatment of tin-wolfram-copper ores at the Clitters United Mines..... 1479
Dolcoath mine, tin in....322, 323, 324, 326, 327, 329g, 331, 341, 358, 380, 389, 422a, 440, 469, 470, 475, 1084, 1320, 1666
Drew on tin in..... 377
Drift Moor near Penzance, tin at..... 355
Dufrénoy and Beaumont on tin in..... 378
Earl of Mount Edgcumbe on tin production, 1873–1883..... 1681
East Wheal Lovell, tin in.....383, 458
Edmonds on Phœnician tin trade with..... 1389
Falmouth, tin near.....411, 459, 1398
Fawns on the Dolcoath mine.....1084, 1320
Ferguson on dressing of tin and copper ores in..... 1654
Flett on brecciated stanniferous vein stones in..... 380
Flett on Dolcoath, Wheal Basset, South Crofty, Carn Brea, Wheal Kitty, and West Kitty mines..... 380
Flett (Reid and) on tin in the Lands End district..... 448
Foster on andrewsite at the West Phœnix mine, Liskeard..... 1608
Foster on the Great Flat Lode at Redruth and Camborne..... 385
Foster on tin in.....382, 386

Cornwall—Continued. Reference Number
Foster on tin at East Wheal Lovell ... 383
Foster on tin at Park of Mines ... 384
Foullon on tin in ... 1322
Fowey Harbor, tin in ... 1407
Fox on tin and copper veins in ... 388
Frecheville on results obtained by Cornish system of dressing tin ores ... 390, 1655
Frecheville on tin at Dolcoath, Cooks Kitchen, Tincroft, and Carn Brea ... 389
Fuchs and de Launay on tin in ... 391
Garby on a catalog of the minerals found in ... 392
Geach (Webb and) on the Caradon and Liskeard district ... 484
Germoe, tin in ... 420
Goonbarrow mine near St. Austell ... 363
Graham on early history of tin in ... 1324
Great Vor district, tin in ... 317
Great Work mine, tin in ... 420
Gunnislake, tin near ... 1479
Hancock on Old Wheal Vor ... 394
Hawkins on ancient tin trade in ... 1395
Hawkins on gold in stream tin in Ladock ... 395
Hawkins on Huel Wherry mine, near Penzance ... 396
Hawkins on origin of alluvial strata of ... 399
Hawkins on Polgooth mine ... 397
Hawkins on tin in ... 398
Headden on the Trethellen tin works, Truro ... 1617
Helmhacker on tin in ... 400
Henty on Wheal Vor mines ... 401
Henwood on Carnon, Nancothan, and Bog deposits ... 402
Henwood on manipulation of tin and copper ores in ... 1656
Henwood on metalliferous veins and ores of ... 403, 405
Henwood on Providence mines near St. Ives ... 406
Henwood on stream tin deposits of ... 402
Henwood on tin in ... 404, 407, 408
Hicks on treatment of slime tin in ... 1657
Hill on tin in ... 409, 410
Hill and MacAlister on tin in Falmouth, Truro, Redruth, and Camborne ... 411
Huel Peever mine, tin in ... 488
Huel Wherry mine, tin in ... 396
Hunt on history of tin mining in ... 1397
Hunt on production of tin and copper in ... 412
Hunt on tin mines, ore produced, and prices, 1864–1873 ... 1687
Hutchin on tin dressing at South Crofty mine ... 1507a
Hutchinson on stokesite, a new mineral from ... 1620

Cornwall—Continued. Reference Number
James on tin in Falmouth Harbor.... 1398
Jars on tin in.... 416
K————, W., on tin in.... 417
Kerl on tin in.... 419
Kerl on tin in Carclaze near St. Austell.... 418
Kitto on Great Work mine, in Breage and Germoe.... 420
Klaproth on chemical examination of tin ore from.... 1513
Ladock, gold in stream tin in.... 395
Lands End district, tin in.... 448
de Lapparent on tin in.... 1335
de Launay (Fuchs and) on tin in.... 391
Le Grice on tin on Trereife, near Penzance.... 1518
Leifchild on mines in.... 422
Levant, tin in.... 343, 460
Levant (St. Ives and) district, tin in.... 315, 460
Lington on the Dolcoath copper and tin mine.... 422a
Liskeard (Caradon and) district, mining in.... 484
Liskeard, West Phœnix mine, andrewsite at.... 1608
Lobley on tin in.... 423
Lobley on tin and copper mining in east.... 423
Lock on tin in.... 424, 1338
Louis on Cornish process of smelting tin.... 1523
Louis on tin in.... 1340
MacAlister on tin in.... 427, 1659
MacAlister on production of tin, copper, etc., in.... 1693
MacAlister on productive tin and copper deposits of Camborne.... 426
MacAlister on vertical distribution of ores in Camborne lodes.... 425
MacAlister (Ussher and) on tin mining in.... 481
Maclaren on gold and tin in.... 428
Maclean on tin mining during 14th century.... 1403
Maclean on history of tin trade in.... 1404
Martin on tin mining in.... 430
Maynard on section through Carn Brea Hill.... 431
Merret on tin in.... 432
Moissenet on tin in.... 433, 434, 435
Myrick on tin concentration in.... 1541
Nancothan tin deposit.... 402
Newland on tin industry in.... 436, 437
Newquay, cassiterite pseudomorphs at.... 1638
Newquay, geology of country near.... 449, 1638
Oxland on possibility of reviving mining industries of.... 438
Paris on tin in.... 439
Park of Mines, near St. Columb, tin at the.... 321, 384
Pearce on cobalt with tin in Dolcoath mine.... 440
Pearce on oxide of tin after quartz and allophane in.... 1629

Cornwall—Continued. Reference Number
Pearce on tin in ... 441
Pearce on tin in Fowey Harbor ... 1407
Pemberthy on tin in, *see* No. 467.
Pennance mine, near Falmouth ... 459
Pentowan mine, tin in ... 345
Pentuan, alluvial strata at ... 399
Pentuan, Happy Union mine, tin in ... 360
Penzance, "Jew's House" at Trereife near ... 1518
Penzance, tin near ... 355, 396, 1518
Phillips (J. A.) on St. Agnes mine ... 1632
Phillips (J. A.) on tin in ... 442
Phillips (Wm.) on tin in ... 1633
Phillips (Wm.) on the Tincroft mine ... 443
Phœnician tin trade with ... 1389, 1400, 1414, 1418
Polgooth mine, tin in ... 345, 397, 1278
Polwhele on history of ... 1409
Porth Ledden Mills, treatment of tin ores at ... 331b
Posepny on tin in ... 1351
Providence mines, tin in ... 406
Pryce on the milling and metallurgy of tin, copper, and lead in ... 444
Rammelsberg on analyses of stannite from ... 1637
Rashleigh on alluvial deposits of ... 447
Ray on tin smelting in ... 1554
Red River, effect of tin tailings on ... 482a
Red River, loss of slime tin in ... 1657
Redruth, tin in ... 313, 331, 385, 411, 473
Reid and Flett on tin in the Lands End district ... 448
Reid and Scrivenor on geology of country near Newquay ... 449, 1638
Restronguet, alluvial tin at ... 329c
Restronguet Creek, tin on ... 464
Reyer on tin in ... 450
Rickard on improvement in mining methods in ... 450a
Rosewarne (Borlase and) on tin in ... 347
St. Agnes district, tin in ... 338, 374, 449, 1603
St. Agnes district, Huel Coates mine, pseudomorphous tin oxide after feldspar in ... 1603
St. Austell, tin mines near ... 363, 418
St. Ives, discovery of tin at ... 1278
St. Ives, tin near ... 406
St. Ives and Levant district, tin in ... 315, 460, 1278
St. Just, tin at ... 349, 353, 354
Salmon (?) on the St. Ives and Levant district ... 315
Salmon (A. L.) on tin in ... 453
Salmon (H. C.) on tin in ... 454
Saunders on ancient tin trade with Phœnicians ... 1414

Cornwall—Continued. Reference Number
Scrivenor (Reid and) on geology of country near Newquay.....449, 1638
Sexton on smelting and refining of tin in..... 1361
Simmons on occurrence of tin, copper, iron, and lead ores in..... 455
Skewes on magnetic separation of tin and wolfram at Gunnislake Clitters 1662
Skewes on tin mining in..... 456
Smith on Phœnician trade with, and on antiquity of tin mining in.. 1418
Solly on tin crystals of various mines of..... 1640
South Crofty mine.....329g, 380
South Crofty mine, tin dressing at.....331b, 1507a
South Wheal Breage mine, tin in..... 420
Spargo on statistics of tin in..... 1699
Stelzner on tin in East Wheal Lovell..... 458
Stephens on mines of Levant, St. Ives, and Zennor..... 460
Stephens on the Pennance mine near Falmouth..... 459
Spencer on stannite from..... 1641
Symons on Carclaze tin mine..... 463
Symons on geology of..... 462
Symons on tin and china clay at Carclaze..... 463
Taylor (C. D.) on tin on Restronguet Creek near Truro..... 464
Taylor (J.) on business methods in tin mines of..... 1663
Taylor (J.) on history of tin mining in..... 1419
Taylor (J.) on tin smelting in..... 1576
Thiollier on metallurgy of ores in..... 1579
Thomas (C.) on mining in.....465, 466
Thomas (H.) on tin in..... 467
Thomas (J.) on Dolcoath mine.....469, 470
Thomas (R.) on survey from Chasewater to Camborne..... 471
Thomas (R. A.) on tin output of..... 472
Thomas (R. Arthur) on Dolcoath mine.....1666
Thomas (Richard A.) on Wheal Uny, near Redruth..... 473
Thomas (Wm.) on Carclaze and Carn Brea mines..... 474
Thomas and Burrows on the Dolcoath mine..... 475
Tincroft mine, tin at.....314, 329g, 389, 443
Trasenster on statistics of tin in, 1879–1881.....1700
Tredinnick on tin in..... 476
Tregaskis on tin in..... 477
Trereife, near Penzance, "Jew's House" at..... 1518
Trereife, tin on..... 1518
Trethellen tin works, Truro..... 1617
Truro, tin near.....411, 464, 1617
Tweedy on minerals in..... 478
Tylor on tin in..... 1420
Unwin on exportation of tin from..... 480
Ussher and MacAlister on tin mining in..... 481
Vivian on history of copper and tin mining in..... 481a

Cornwall—Continued. Reference Number
Wait on tin mines of ... 482
Walker on effect of tin tailings on Red River ... 482a
Warner on tin in ... 1421
Watson on system of mining and statistics of tin in ... 483
Webb and Geach on the Caradon and Liskeard district ... 484
Weeks on tin deposits of ... 1372
West on tin mining in ... 485
West Kitty mine ... 380
Wheal Bassett, geology of ... 331b
Wheal Bassett, tin in ... 380
Wheal Breage, tin in ... 420
Wheal Kitty, use of impact screen at ... 1652
Wheal Kitty, tin in ... 380
Wheal Prosper, tin at ... 318
Wheal Uny, near Redruth, Great Flat Lode in ... 473
Wheal Vor, tin in ... 329g, 330, 394, 401
Williams (A.) on tin mines of ... 487
Williams (J.) on the Huel Peever mine ... 488
Williams (R. H.) on tin in St. Austell district ... 489
Woodward on tin ore specimens from ... 489a
Worth on antiquity of tin mining in ... 1421
Worth on mining, dressing, smelting, and sale of tin and copper in ... 1425
Worth on tin in ... 1426
Zennor, tin in ... 460
Zirkel on tin in ... 490
See also England.
Correze (Meymac), *see* France.
Coruña, *see* Spain.
Corundum, *see* Association of tin with.
Cotta, Bernard von ... 65, 371, 501, 537, 538, 539, 540, 541, 1312
Cotton, Leo A. ... 816a
Couch, R. Q. ... 372
Counsel, E. A. ... 1079
Country Harbor, *see* Nova Scotia, Lunenberg County.
Courtis, W. M. ... 24
Courtney, W. P. (Boase, G. C., and) ... 342
Cowper, Coles S. ... 1471
Cox, Herbert S. ... 817
Coxs Bight, *see* Tasmania.
Coya lode, *see* Bolivia.
Cramer, Carl ... 682
Cramer, John Andrew ... 1472
Crawfurd, John ... 282
de Cressac, C. ... 502, 503
Cretaceous, tin ore in ... 155, 182
Crettier, H. ... 88, 127, 283

Reference Number

Creuse, *see* France.
Cristal Mountains, *see* French Kongo, Crystal Mountains.
Croaghan Mountains, *see* Ireland, Wicklow.
Croghan Kinshelagh, *see* Ireland, Wicklow.
Cronstedt, Axel F. 1599
Croockewit, H. 683
Croockewit, J. H. 89, 1473
Crook County, *see* Wyoming.
Crookes and Roehrig 1242
Crows Nest deposits, *see* Queensland.
Cryolite, *see* Association of tin with.
Crystal Mountains, *see* French Kongo.
Crystallization of tin and tin compounds:
  Allard on, metal 1429
  Bauer on, cassiterite 1591
  Becke on, cassiterite 1592
  Bernhardi on, metal 1593
  Cronstedt on, cassiterite 1599
  Disintegration of tin upon crystallization 1434
  Foullon on, metal 1609
  Foullon on crystallized tin 1490
  Greg and Lettsom on, cassiterite 1614
  Hiortdahl on, stannmethyles 1505a
  Jackson on, cassiterite 792
  Jermejev on crystals of tinstone from Transbaikalia 1622
  Kohlman on measurements of cassiterite crystals 1624
  Lacroix on distorted cassiterite crystals from France 516
  Miller on measurements of crystals of metallic tin 1627
  Mohlengraaf on distorted cassiterite crystals from Swaziland 1052
  Phillips on the oxide of tin 1633
  Phillips on the cleaving of cassiterite crystals so that the angles may be measured 1634
  Pirsson on crystals of hematite enclosing cassiterite 1635
  Spencer on crystallized stannite from Bolivia 1641
  Trechmann on two forms of crystals obtained in manufacture of metallic tin crystals 1645
  Woolnough on distorted cassiterite crystals from Pilbarra, Western Australia 1649
  See also Mineralogy of tin.
Cudgewa district, *see* Victoria.
Cummings mine, *see* Tasmania.
Cupriferous quartz, *see* Association of tin with.
Cuprite, *see* Association of tin with.
Cuprocassiterite:
  Ulke on a new tin mineral in the Black Hills 1646
  See Association of tin with.

Reference Number

Cuproscheelite, *see* Association of tin with.
Currumbin-Coolangatta, *see* Queensland.
Cussack, W. G. Kelley..... 899
Custer City, *see* South Dakota.
Cylindrite:
Frenzel on a rare tin ore from Bolivia..... 1611
Prior on relations of teallite to..... 1636

D

D————, C. H..... 1386
Dabney, Chas. W..... 241
Dach, Robert..... 284
D'Achiardi, Antonio.....621, 1313
Dahlblom, Th..... 373
Daintree, R..... 900
Dakota, Jaquet on tin in.....825
See also South Dakota.
Dalkey, *see* Ireland, Dublin.
Dalmer, Karl.....542, 543, 544, 622
Damour, A..... 527
Dana, J. D..... 1600
Dartmoor, *see* Devon.
Daubrée, A.....504, 1314, 1315, 1316, 1340, 1601, 1602
Davey, John..... 1080
Davey, Sir Humphrey..... 375
Davey, Stephen..... 1603
Davey, T. G..... 1179
David, T. W. Edgeworth..... 818
Davies, Alfred T..... 374
Davies, D. C..... 1317
Davy, L.....505, 1387
Dawson region, *see* Yukon.
Day, David T.....1004, 1005, 1203, 1203a, 1318, 1319
Dechen, H. von..... 545
Deepwater, *see* New South Wales.
Deer horns, replaced by oxide of tin in Cornwall.....365, 372
Deer horns, Scrivenor on absence of tin in those stated to have been replaced by SnO_2..... 726b
de Kalb, Courtnay..... 1334
de Koninch, L. L., and Lecrenier, A..... 1474
Dela, *see* Ceylon.
De La Beche, Henry T..... 376
Delachanal, B., and Mermet, A..... 1475
De La Croix, J. Errington.....684, 685, 686
de Lapparent, A..... 1335
de Launay, L.....3, 518, 854, 1625

Reference Number

de Launay, L. (Fuchs, E., and) 66, 159, 509, 1323
Delime River, *see* Nigeria.
de Limur (le Comte) 519
Del Mar, Alex 769
de Loos, D 1339
Delume (Kogin-) River, *see* Nigeria.
Delvaux de Fenffe, A 1476
Demarçay, E. (Cahours, A., and) 1461, 1462
Denmark, Bergse process used at Copenhagen for recovery of scrap tin, 1442
Derby, *see* Tasmania.
Derrick, W. H 687
Deville, H. Saint-Claire 1604
Deville, Saint-Claire H., and Caron, H 1605
Devon, tin in 312
Anonymous, *see* also W. K.
Ashburton, stannary of 1427
Bennetts on tin in Dartmoor 337
Berger on the physical structure and mines of 339
Boase and Courtney on tin mining in 342
Burnard on Stannaries in, and on the antiquity of mining in 1384
Busz on hornfels, garnet-datolite hornfels, and hedenbergite hornfels in Dartmoor 350
Collins on history of tin production in 1385
Collins on origin and development of ore deposits in 367
Collins on tin in 361, 364
Collins on tin production, 1201–1800 1680
Combes on tin in 370
Courtney (Boase and) on tin mining in 342
Dartmoor, tin in 337, 350
De La Beche on tin in 376
Foster on tin in 382
Henwood on the metalliferous veins and ores of 403, 405
Hill on tin in 409
Hunt on tin in 413, 414
K————, W., on tin in 417
Moissenet on tin in 434
Oxland on possibility of reviving mining industries of 438
Spargo on statistics of tin in 1699
Stannaries, laws and customs of the 1384
Taylor on business methods in tin mines of 1663
Taylor on history of tin mining in 1419
Taylor on tin smelting in 1576
Thomas (C.) on mining in 465, 466
Tregaskis on tin in 477
Worth on antiquity of tin mining in 1426
Worth on mining, dressing, smelting, and sale of tin and copper in .. 1425

Devon, tin in—Continued. Reference Number
Worth on stannary of Ashburton 1427
See also England.
Devonian, tin mines of New South Wales and Queensland occur in the.. 814
Tin in, in Bolivia 180a
Twelvetrees on tin veins in a granite boss of Devonian age in Tasmania 1147
Waller on tin in granite of Devonian age cutting Silurian sediments, 1155
Dew, J. H. W 376a
Dewey, Fred P 1477
Diamonds, Voit on deposits of in South Africa 3c
See Association of tin with.
Diest, P. H. van 90, 91, 92, 93, 94, 128, 285, 286, 1478
Dietzsch, F 1479
Dijk, P. van 95, 96, 690, 1081, 1082, 1480
Dindang district, *see* Billiton.
Dindings, *see* Malay Peninsula, Perak.
Dinsmore, Chas. A 1168a
Diopside, *see* Association of tin with.
Ditte, A 1606
Djeboes district, *see* Banka.
Dogtown, *see* South Dakota.
Dolcoath mine, *see* Cornwall.
Dominican Republic, *see* Santo Domingo.
Doormann, W. H. C 286a
Doornhoek, *see* Transvaal.
Doren, J 97
Dorfhain, *see* Germany.
Dorset County, *see* Tasmania.
Douglas, J. C 1481
Douglas, Jas 1204
Dowel, W. S 901
Doyle, P 689
Doyle, Patrick 688
Dredging, Fawns on methods used in dredging for tin 1320
Dressing of tin ore:
Baldauf on methods in Cornwall 331
Ball, comparison of Cornish methods with those of Queensland 331a
On Cornish methods 331b
Boase on method in Cornwall 343
Bolivia 177
Brackenbury on 1455a
Carcanagues on, in Cornwall 1651
Carew on methods in Cornwall 351
Charleton on 1310
Cleland on methods at Stannary Hills, Queensland 897
Collins on methods in Cornwall 368

Dressing of tin ore—Continued. Reference Number
Collins on use of impact screen in..... 1470
Cornwall....312, 331, 331a, 331b, 343, 351, 368, 390, 403, 419, 490, 1425, 1650, 1651, 1654, 1655, 1656, 1659, 1666
Commans on concentration and sizing of crushed minerals..... 1653
Davey on losses in at Mount Bischoff, Tasmania.....1080
Devon 312, 403, 1425
Fawns on tin crushing and dressing machinery..... 1320
Ferguson on, in Cornwall..... 1654
France, Montebras, ore dressing plants in..... 496
Frecheville on losses of black tin in Cornish system of..... 390
Frecheville on results obtained by the Cornish system of..... 1655
Germany, Altenberg..... 528
Gower on machinery used in Vegetable Creek tin field, New South Wales.....821, 822, 824
Henwood on, in central mining district of Cornwall..... 1656
Henwood on methods in Cornwall and Devon..... 403
Hutchin on.....1507a, 1507b
Kerl on methods in Cornwall..... 419
Losses in dressing Cornish ores.....1650, 1655
MacAlister on, in Cornwall..... 1659
Malay Peninsula.....676c, 704a
Menniche on separation of silver, lead, bismuth, tungsten, and copper from tin ores..... 1534
Mills-Davies on plant at Kooiberg, Transvaal.....1185a
New South Wales, Vegetable Creek district.....821, 822, 824
Pearce on application of chemistry to..... 1546
Phillips on improvements in..... 1661
Pryce on..... 444
Purnett on methods in Bolivia..... 177
Queensland 331a, 897
Rowe on chemical methods of treating ores..... 1560
Sexton on..... 1361
South Africa..... 3d
South Dakota, Black Hills.....983, 986
Tasmania 1080
Terrell on final stages in.....1576a
Terrell on the final stages of tin and wolfram dressing..... 1664
Thomas (Chas.) on reducing waste resulting from..... 1665
Thomas (R. A.) on treatment of tin ore at Dolcoath mine, Cornwall, 1666
Transvaal 1185a
Tregay on..... 1667
Weston on methods in South Africa..... 3d
Worth on methods in Cornwall and Devon (historical)..... 1425
Zirkel on methods in Cornwall..... 490
See also Metallurgy of tin, milling of tin, refining of tin, and smelting of tin. *See* references Nos. 1428–1587 and 1650–1668.

Reference Number

Drew, S. 377
Drift Moor, *see* Cornwall.
Dry Forest Creek, *see* Victoria.
Dry River, *see* Queensland.
Dublin, *see* Ireland.
Dufrené, Hector 1388
Dufrénoy, P. A. 506
Dufrénoy, P. A. (Juncker and) 513
Dufrénoy, P. A., and Beaumont, Élie de 378
Dufrénoy, P. A., and Juncker 507
Dumble, E. T. 1169
Dundee, *see* New South Wales.
Dunstan, B. 902-905
Dunstan, R. W. 786
Dunstan, Wyndham R. 258, 647, 857, 858, 859
Durangite:
  Hanks on occurrence of, in Durango, Mexico 774
  See Association of tin with.
Durango, *see* Mexico.
Durocher, M. J. 508
Dussance 1482
Dutch East Indies, tin in 675, 1298
  Day on tin in 1318
  Doorman on tin in 286a
  Lock on tin in 1338
  See also Banka, Billiton, Borneo, Celebes, East Indies, Java, and Sumatra.
Dykes, F. J. B. 691, 692, 693, 1483
Dykes, F. J. B. (Hume, W. J. P., and) 698

E

E———, C. 49
Ears Mountain, *see* Alaska.
Earl of Mount Edgcumbe 1681
East Indies:
  Crawfurd on tin in 282
  Cretier on tin in Java, Billiton, and the Dutch East Indies 283
  D'Achiardi on tin in 1313
  D'Achiardi on tin on Karimon Island 284
  Diest on tin in Salinta 286
  Diest on tin in Singkep Island 285
  Doorman on tin in the Dutch East Indies 286a
  Everwijn on tin at Sukadana, Simpang, Matan, and Palo 291
  Everwyn on tin in the Riouw Islands 289

East Indies—Continued. Reference Number
Everwyn on tin in Sukadana, Simpang, Matan (Borneo), and Karimata 287
Fawns on tin in 1320
Flores, tin in 301
Fuchs and de Launay on tin in 1323
Hochstetter on tin in 295
Karimata, tin in 287
Karimon Island, tin in 284
de Lapparent on tin in 1335
de Launay (Fuchs and) on tin in 1323
Lock on tin in 1338
Menten on tin in Singkep 297
Palo, tin in 291
Posewitz on tin in the Riouw-Linga Archipelago 300
Posewitz on tin in Sumatra, Borneo, and Flores 301
Reyer on tin in 1354
Riouw Islands, tin in 289
Riouw-Linga Archipelago, tin in 300
Salinta, tin in 286
Schneider on tin in 306
Singkep Island, tin in 280, 285, 297, 308, 1284
Smyth on tin in 1362
Wildman on tin in Singkep 308
See also Banka, Billiton, Borneo, Burmah, Celebes, Dutch East Indies, Java, Siam, Straits Settlements, and Sumatra.
East Pool mine, *see* England.
East Wheal Lovell, *see* Cornwall.
Échassières, *see* France, Allier.
Echo mine, *see* Tasmania.
Eddy, William 1225
Edlinger, W. 906
Edmonds, Richard 1389
Edwards, C. P. 1483a
Egleston, T. 1484
Egypt, George on bronze article found in 1392
Winer on the metals and minerals of the ancient Egyptians 1424
Egyptians, George on mining and use of metals by 1392
Ehrenfriedersdorf, *see* Saxony.
Ehrenwerth, J. von 1682
Eibenstock, *see* Saxony.
Elba, *see* Italy, Tuscany.
Eldorado, *see* Victoria.
Electrolytic deposition of tin 1290
Elisa lode, *see* Bolivia.
Elk Gulch, *see* South Dakota, Black Hills.

Reference Number

Ellis, Thos. F. (McKillop, John, and) 1530
El Paso, *see* Texas.
El Paso tin deposits, *see* Texas.
Elsmore mine, *see* New South Wales, Inverell.
Elsner, L. 1485, 1486
Embabaan, *see* Swaziland.
Embickelweni, *see* Swaziland.
Emerald, *see* Association of tin with.
Emerald mines, *see* New South Wales, Emmaville.
Emmaville district, *see* New South Wales.
Emmens, Stephen H. 1006, 1205
Emmons, S. F. 155, 270, 1206
Endter, Augusto 155a
Engel, R. 1487, 1488
England:
- Abbott on tin in 309
- Baldauf on Redruth, Dolcoath, and East Pool mines 331
- Bartlett on British mining 334
- Batten on tin in 1377
- Bawden on dislocation of lodes and strata in 335
- Beck on tin in 1299
- Boase on tin of Botallack 343
- Botallack, tin of 343
- Brown on tin in 1307, 1308
- Bunter pebble bed, cassiterite in 468
- Burrows (Thomas and) on tin in 475
- Carne on tin in 356
- Carne on the Relistian mine 352
- Chapman on tin in 1597
- Collins on history of tin production in 1385
- Collins on "Jew's tin" in 362
- Collins on tin in 367, 369, 1385
- Collins on tin and gold at Treloy 369
- D'Achiardi on tin in 1313
- Davies on tin in 1317
- Dechen on tin in 545
- De La Beche on tin in Cornwall, Devon, and Somerset 376
- Dixon on tin in, *see* No. 448.
- East Pool mine, tin in 331
- Edmons on causeway between Marazion and St. Michael's Mount, etc., 1389
- English on British mining companies 379
- English on tin mines of 379
- Falmouth Harbor, block of tin dredged in 1398
- Foster on the Rosewarne mine 381
- Foster on tin in Cornwall, Devon, and Somerset 382
- Fowey Harbor, blocks of tin dredged from 1407

England—Continued. Reference Number
Fox on tin in Wendron ... 387
Geological Survey maps showing tin deposits ... 429
Greg and Lettsom on tin in ... 1614
Gregor on muriate of tin from ... 393
Hawkins on alluvial strata at Porth, Sandrycock, and Pentuan ... 399
Hawkins on history of tin mines in ... 1396
Henwood on tin in ... 1327
Hunt on mines of ... 415, 1688
James on block of tin dredged in Falmouth Harbor ... 1398
Jars on tin in ... 416
Kudernatsch on tin in ... 421
Lancashire, condition of manufacturing chemistry in ... 1568
Lettsom (Greg and) on tin in ... 1614
Lewis on history of tin mining in ... 1402
Louis (Phillips and) on tin in ... 1350
MacAlister on tin in, *see* Nos. 448 and 449.
Pearce on blocks of tin dredged in Fowey Harbor ... 1407
Phillips and Louis on tin in ... 1350
Plinius on tin in ... 1408
Pollard on tin in, *see* No. 448.
Porth, alluvial strata at ... 399
Pryce on minerals, mines, and mining of ... 444
de Rance on stream tin in ... 446
Relistian tin mine ... 352
Rhys on early tin trade of ... 1413
Rosewarne mine ... 381
Rudler on minerals in British Isles ... 452
Sandrycock, alluvial strata at ... 399
Schnabel on tin in zinc from ... 794
Schunck, Smith, and Roscoe on condition of manufacturing chemistry in South Lancashire district ... 1568
Smyth on occurrence of copper and tin in ... 457
Thomas on cassiterite in Bunter pebble bed in west of ... 468
Thomas and Burrows on tin in ... 475
Treloy, tin and gold at ... 369
Watson on British mining ... 483
Wendron, tin in ... 387
Wilkinson on tin in, *see* No. 448.
Woodward on a catalogue of fossils from ... 489a
Worth on antiquity of tin mining in ... 1426
See also Cornwall, Devon, Europe, Great Britain, and Somerset.
English, A. G. ... 50
English, Henry ... 379
Enkeldoorn, *see* Transvaal.
Enterprise mine, *see* South Australia.

Reference Number

Epidote, *see* Association of tin with.
Erea Dam, *see* South Australia.
Ernst, C. von 623
Erzgebirge, *see* Saxony.
Eschwege, W. von 874
Eskdale, *see* Victoria, northeastern district.
Esk River, *see* New South Wales, Richmond County.
Etta mine, *see* South Dakota.
Eureka Creek district, *see* Queensland.
Euriowie, *see* New South Wales.
Europe, Bergman on tin veins of 1302
Louis on tin in 1340
Rolker on tin in 1357
See Austria, Bohemia, Cornwall, Devon, England, Finland, France, Germany, Ireland, Italy, Norway, Portugal, Russia, Saxony, Scotland, Siberia, Spain, Sweden.
Euxinite, *see* Association of tin with.
Evans or Little River, *see* New South Wales.
Everding 155b
Everwijn, R. 98, 289, 290, 291
Everwyn, R. 287, 288
Evigtok, *see* Greenland.
Ewen, D. (Levy, D. M., and) 1521a
Exportation of tin:
China, 1904 266
Indian Archipelago 282
Sumatra, Siak district 305
Victoria, 1899 to date 1222

F

Fairbanks, Harold W. 215, 216
Fairbanks region, *see* Alaska.
Fairibault, E. Rodolphe 227
Falls Church, *see* Victoria.
Falmouth, *see* Cornwall and England.
Farrell, John R. 276
Fasal, J. (Fraenkel, A., and) 1493
Fatigue of metals, Egleston on fatigue and refreshment of tin 1484
Fawns, Sydney 156, 277, 694, 770, 1083, 1084, 1320
Fay, Albert Hill 25
Feather River, *see* California, Plumas County.
Feldspar:
Associated with tin 498, 586, 681
Cassiterite pseudomorphs after 357, 478, 479, 1603, 1638
Reid and Scrivenor on cassiterite pseudomorphs after 1638

Feldspar—Continued. Reference Number
Replaced by SnO_2 in Cornwall ... 357
Replaced in turn by tourmaline and SnO_2 in Tasmania ... 1078a
Tweedy on cassiterite pseudomorphs after ... 478, 479
See also Association of tin with.
Fennema, R. ... 292, 293
Ferguson, Henry T. ... 1654
Ferguson Island, *see* New Guinea.
Fergusonite, *see* Association of tin with.
Fermor, L. Leigh ... 590a
Ferrier ... 129
Feuchtwanger, Lewis ... 1321
Fichtelgebirge, *see* Germany.
Fiedler, K. G. ... 943
Field, Frederick ... 1607
Fillery Creek, *see* Alaska.
Financial side of tin:
Abbott on the mines of England ... 309
Banka, 1827 ... 113
Bettany on the tin trade, 1866 ... 1304
Burmah, Mergui district, 1845 ... 206
Burmah, Mergui district, 1889 ... 185
Cornwall:
Coinage of tin and commercial practices of ... 351
Cost of operating, production, and wages ... 422
Financial outlook, 1900–1901 ... 328
Profits derived from mines in ... 476
System of selling ore in ... 316
England, cost book system in ... 334
England, mining companies in ... 379
General ... 1291
Indian Archipelago, 1820 ... 282
London tin market in 1902 and 1903 ... 1346, 1347
Malay Peninsula, 1900 ... 712
Malay Peninsula, 1903 ... 681
Malay Peninsula, industrial position of tin fields of ... 729
Newland on New York and London tin markets in 1902 and 1903, 1346, 1347
New York tin markets in 1902 and 1903 ... 1346, 1347
Perak, 1896 ... 660
Perak, economic conditions ... 686
Perak, Tambun mine, profits, 1904 ... 670
Struthers and Pratt on market conditions in the United States in 1903 ... 1364
Tasmania, commercial conditions in ... 1106
Tasmania, Mt. Bischoff, costs of mining in ... 1083, 1102, 1105

Financial side of tin—Continued. Reference Number
Tasmania, Mt. Bischoff, dividends....1121a
United States, imports, market conditions, and prices of tin in 1907.. 1211
United States, market condition in 1903.... 1364
United States, tin plate industry, prices, exports, etc.... 1202
Finistère, *see* France.
Finland:
Borgström on tin at Pitkäranta.... 1594
Cotta on tin in.... 1312
Fawns on tin in.... 1320
Gadolin on tin at Pitkäranta 1612
Gurney on tin at Pitkäranta, near Lake Ladoga.... 944
Keppen on tin in....946, 969
Koulibine on tin production of Pitkäranta, 1887–1889....1691, 1692
Krusch on tin at Pitkäranta.... 947
Ladoga (Lake) tin near.... 949
Louis on tin in.... 1340
Nordenskiöld on tin in....948, 1628a
Phillips and Louis on tin in.... 1350
Pitkäranta, iron, copper, and tin ores at.... 953
Pitkäranta, tin at....942, 944, 947, 948, 950, 951, 952, 953
Rusch on tin near Lake Ladoga and elsewhere in Finland.... 949
Schoultz-Ascheraden on tin at Pitkäranta.... 950
Somero, ainalite from Pennikja in....1628a
Struve on tin at Pitkäranta.... 951
Törnebohm on tin at Pitkäranta.... 952
Trüstedt on iron, copper, and tin ores at Pitkäranta.... 953
Trüstedt on tin at Pitkäranta.... 953
See Russia and Europe.
Fircks, F. W. von.... 1085
Fischer, H....39, 961
Fitton, William 600
Flett, J. S.... 380
Flett, J. S. (Reid, Clement, and).... 448
Flett, J. S., and Clough, C. T.... 955
Flink, Gust.... 582
Flores Island, *see* East Indies.
Flower, Phillip Wm.... 1390
Flower-Ellis, T. J.... 1489
Fluorine, *see* Association of tin with.
Fluorite, *see* Association of tin with.
Fluorspar, *see* Association of tin with.
Foniakoff, Antonin....965, 966
Forbes, David.... 157
Forbes Reef, *see* Swaziland.
Foss, K. Mackenzie.... 188
Fossilbrook, *see* Queensland.

Reference Number

Foster, C. Le Neve 381, 382, 383, 384, 385, 386, 1608
Foster, C. Le Neve (Rowe, T. P., and) 451
Foullon, H. 1322
Foullon, H. von 1490, 1609
Fouqué, F., and Lévy, Michel 1610
Fowey Harbor, *see* Cornwall.
Fox, Charles 387
Fox, Robert Were 388
Fraenkel, A., and Fasal, J. 1493
Fraenkel, S. 99
France:
  Allier, tin in 516, 1316
  Allier, Colettes, tin at 509, 510
  Allier, Échassières, tin at 510
  Allier, Lizolle and Échassières, tin with kaolin at 504
  Anjou, tin at 516
  Audibert on tin veins of Maupas, Morbihan 497
  Baudot on tin at Villeder, Morbihan 498
  Beck on tin in 1299
  Blavier and Lorieux on tin at Villeder, Morbihan 499
  Bourbonne, tin in an altered lead at 1316
  Brittany:
    History of tin trade in 1416
    Tin deposits of 501, 508, 516
  Burthe on tin at Meymac 500
  Chanteloube, tin at 509
  Charente, tin in 516
  Cieux, tin at 509
  Corrèze (Meymac), tin in 516
  Cotta on tin in 1312
  Cotta on tin deposits of Brittany 501
  Cressac on tin in 502, 503
  Creuse, tin in 509, 516, 522
  D————, C. H., on ancient tin mines of Limousin and La Marche 1386
  D'Achiardi on tin in 1313
  Daubrée on occurrence of tin ore in 1314
  Daubrée on tin in an altered lead at Bourbonne 1316
  Daubrée on tin oxide in kaolin in Allier 1316
  Davies on tin deposits of 1317
  Davy on tin between Abbaretz and Vay in Lower Loire 505
  Dufrénoy on tin in 506
  Dufrénoy on tin at Piriac, Lower Loire 507
  Dufrénoy (Juncker and) on tin at Piriac, Lower Loire 513
  Durocher on tin in Brittany 508
  Fawns on tin in 1320

France—Continued. Reference Number
Finistère, tin in ... 516
Fuchs and de Launay on tin in ... 1323
Fuchs and de Launay on tin at Villeder, Montebras, Creuse, Vaulry, Cieux, Colettes (Allier), Chanteloube, and St. Leonard ... 509
Guédras on tin in Barjac, Lozére ... 511
Haute-Vienne, tin in ... 516
Haute-Vienne, St. Leonard, gold at ... 1406
Haute-Vienne, St. Leonard, tin at ... 509
Hersart on tin in Lower Loire ... 512
Ille-et-Vilaine, tin in ... 514
Juncker and Dufrénoy on tin at Piriac, Lower Loire ... 513
Kerforne on tin at Ille-et-Vilaine ... 514
Kerndt on tin at Piriac, Lower Loire ... 515
Lacroix on tin in France and her colonies ... 516
La Marche, tin deposits of ... 523, 1386, 1406
de Lapparent on tin in ... 1335
Lassalle on tin in Montebras ... 517
de Launay on lithine and rare minerals in Montebras ... 518
de Launay (Fuchs and) on tin in ... 1323
Limousin, tin in ... 523
Limousin, working of ancient tin mines in ... 1386, 1406
de Limur on tin in Villeder ... 519
Lodin on tin in Pontgibaud, Puy-de-Dome ... 521
Lodin on tin in Villeder ... 520
Louis on tin in ... 1340
Louis (Phillips and) on tin in ... 1350
Lower Loire, tin in ... 512, 516
Lower Loire, Abbaretz and Vay, tin between ... 505
Lower Loire, Piriac, tin at ... 507, 513, 515
Lozère Barjac, tin in ... 511
Maine-et-Loire, tin in ... 516
Mallard on tin at Montebras ... 522
Mallard on tin deposits of Limousin, La Marche, and Vaulry ... 523
Mallard on ancient tin mines of Limousin and La Marche ... 1386
Manche, Pieux, tin at ... 491
Maures, tin in ... 516
Mazade on the minerals in the mineral waters of Neyrac ... 524
Meymac, tin at ... 500, 516
Montebras, tin in ... 494, 496, 509, 517, 518, 522, 1289, 1406
Morbihan, tin in ... 497, 516
Morbihan, Maupas, tin in ... 497
Morbihan, Villeder, tin at ... 498, 499, 509, 519, 520, 526
Neyrac, tin at ... 524
Pattison on ancient tin mines of Limousin and La Marche ... 1406
Phillips and Louis on tin in ... 1350
Puy-de-Dome, tin in ... 516

	Reference Number
France—Continued.	
Puy-de-Dome, Pontgibaud, tin at	521
Sénez on tin in	525
Simonin on ancient tin mines of Limousin and La Marche	1386
Simonin on history of tin trade in Brittany	1416
Simonin on tin in Villeder	526
Vaulry, gold at	1406
Vaulry, tin near	495, 509, 523, 1406
See also Europe.	
Franckeite, Prior on relations of teallite to	1636
Stelzner on, from Bolivia	1642
Frangken, V.	1491
Franklin, *see* Victoria.	
Franklin Mountains, *see* Texas.	
Fraser, *see* Malay Peninsula, Telom.	
Frecheville, R. J.	389, 390, 1655
Frederikshaabs, *see* Greenland.	
Freiberg, *see* Germany.	
Freiesleben, J. C.	546, 547
French Guiana, Approuague River, tin from	527
Damour on tin on the Approuague River	527
See also South America.	
French Kongo:	
Barrat on tin in the Crystal Mountains	272
Crystal Mountains, tin in the	3, 272
de Launay on tin in	3
"Massinga or Massinda" (Masinde?) north of "Agapota" in the basin of the "Banghi" (Ubangi?), tin at	3
Stanier on tin on the Ubangi and Welle (Djabbir)	279
Ubangi, tin on the	3, 279
Welle (Djabbir), tin on the	279
Welle Makwa, tin on the	3
See also Kongo and Africa.	
Frenzel, A.	1611
Fritzche, P.	1492
Frochot, Maurice	158
Fryar, Mark	189
Fryar, Wm.	907
Fuchs, E.	391
Fuchs, E., and de Launay, L.	66, 159, 509, 1323
Fumachhio, *see* Italy, Tuscany, Monte Fumachhio.	
Furman, John H.	242, 242a
Furnaces, Collins on adobe and other cheap	1468
Lesley on furnaces, forges, and rolling mills of the United States	793
Used in roasting tin and copper ores in Cornwall	1656
See also Metallurgy of tin.	

G

Reference Number

Gades (Cadiz), Lewis on tin in ... 1401
Gadolin, S. A. ... 1612
Gadolinite, *see* Association of tin with.
Galæcia, *see* Spain.
Galena, *see* Association of tin with.
Galicia, *see* Spain.
Gallofa lode, *see* Bolivia.
Garby, John ... 392
Garcia, Manuel ... 1032
Garhval, *see* India.
Garland, Joseph ... 1033
Garnet, *see* Association of tin with.
Garrison, F. Lynwood ... 217, 243, 1007, 1207
Garston, E. M. de ... 954
Gascuel, L. ... 643
Gätzschmann, M. F. ... 1391
Gauls, ancient mines believed to have been worked by ... 1386, 1406
Gaultier de Claubry, H. F. ... 1494
Gautier, Ferdinand ... 160
Gay-Lussac, Louis J. ... 1495
Gayndah district, *see* Queensland.
Gem minerals, *see* Association of tin with.
Genth, Frederick A. ... 244, 771, 787, 820
George, R. D. ... 1392
Georges Bay, *see* Tasmania.
Georges River, *see* Tasmania.
Georgia, tin in ... 1281
  Day on tin in ... 1203a
  Rolker on tin in ... 1357
Gerardin, A.? ... 1496
Germanium, in canfieldite ... 1631
Germany, tin in ... 1298
  Beck on tin in ... 531, 1299
  Blöde on tin in ... 533
  Bodenmais, tin in Silberberg near ... 578a
  Breitenbrun, tin near ... 546
  Breithaupt on tin in ... 535
  Brown on tin in ... 1307, 1308
  Cotta on tin deposits of ... 541, 1312
  D'Achiardi on tin in ... 1313
  Dalmer on tin and lead ores in the cobalt field of Schneeberg ... 543
  Davies on tin in ... 1317
  Dechen on tin deposits of ... 545
  Dorfhain, tin near ... 559
  Fawns on tin in ... 1320

Germany—Continued. Reference Number
Fichtelgebirge, tin in the....570, 571
Freiesleben on the pyrites, iron, and tin deposits near Breitenbrunn 546
Fuchs and de Launay on tin in.... 1323
Gätzschmann on tin in.... 1391
Gmelin on geology of.... 548
Greifenstein, cassiterite as rock making mineral in granite of.... 1639
Jars on tin in.... 416
Klaproth on chemical examination of tin ore from.... 1513
Lampadius on tin in.... 1516
de Launay (Fuchs and) on tin in.... 1323
Louis on tin in.... 1340
Louis on German process of smelting tin.... 1523
Louis (Phillips and) on tin in.... 1350
Newland on tin in.... 1347
Nowicki on tin in.... 71
Phillips and Louis on tin in.... 1350
Sandberger on the origin of tin deposits of.... 569
Schertel (Stelzner and) on tin in.... 1643
Schmidt on tin in the Fichtelgebirge....570, 571
Scrap tin recovered and used in....1438, 1497a, 1511
Seegrunde, tin in.... 562
Seiffen, tin near.... 559
Silberberg, tin in.... 578a
Stelzner and Schertel on tin in.... 1643
Weinschenk on tin in Silberberg near Bodenmais.... 578a
See also Saxony and Europe.
Germo, *see* Cornwall.
Gertie property, *see* South Dakota.
Geyer, *see* Saxony.
Giants Den, *see* New South Wales.
Gibson, Walcott.... 2
Giesecke, K. L.... 583
Gilbertite, *see* Association of tin with.
Gil y Maestre, Amalio.... 1034
Gimpu River, *see* Nigeria.
Gimpy River, *see* Nigeria.
Gippsland, *see* Victoria.
Glenlinedale, *see* Queensland.
Gladstone district, *see* Tasmania.
Glasser, E.... 967
Glycium, *see* Association of tin with.
Gmehlin, J. F.... 548
Gmehling, Andreas.... 1497
Godefroy, W.... 100
Godfrey, J. G. H.... 631
Godhavn district, *see* Greenland.

Gold: Reference Number
Andrews on deposits at Table Top, Timbarra, New South Wales.... 797
Argentina, Salta..... 37
Associated with tin, *see* Association of tin with.
Bannister on assaying stream tin for..... 1444
Bechamp and Saintpierre on separation of gold and platinum from tin and antimony..... 1445
Becher on gold bearing formations of the Malay Peninsula..... 678
Billiton 126a
Bolivia 172
Boucard on separation of gold and platinum from tin and antimony. 1455
Brache on mining at Eldorado, Victoria..... 1224
Brown on discovery of, in South Australia..... 974
Burmah 188
Buttgenbach on gold deposits near tin veins in Katanga..... 275
California, near Los Angeles..... 208
Campagne on mines of..... 1309
Carne on source of gold and tin in beach sands of New South Wales.. 809
Castro on gold deposits in Salta, Argentina..... 37
Clarke on researches in gold fields of New South Wales..... 812
Collins on occurrence with tin in west of England..... 369
Cornwall, in placers with tin.....395, 428
de Koninch and Lecrenier on the qualitative separation of gold and platinum from arsenic, antimony, and tin..... 1474
Distribution of..... 1293
Douglas on metallurgy of..... 1204
Eddy on placer deposits in South Gippsland, Victoria, carrying both gold and tin..... 1225
Elsner on the separation of gold and platinum from tin and arsenic. 1486
Emmons on occurrence in United States and genesis of minerals of. 1206
England, with stream tin..... 369
English on deposits of tin and gold near Ovens, Victoria..... 50
Foniakoff on deposits in Siberia..... 965
Hawkins on presence in tin stream works of Cornwall..... 395
Hawkins on superficial production of..... 1330
Herman on occurrence near Bruthen, Victoria..... 1228
Hermann on tin in gold washings of the Ural (Central Asia)..... 40
Ireland 428, 601, 602
Ireland, Wicklow.....599, 600, 605, 607
Johnson on "getting gold"..... 51
Kinahan on occurrence and mining of, in Ireland.....601, 602
Kitson on deposits in Victoria..... 1229
Kongo, Katanga, gold and tin deposits close together..... 275
Lapage on deposits in Western Australia..... 1259
Maclaren on gold and tin in Cornwall and Ireland..... 428
Malay Peninsula.....659, 678, 693, 728

Gold—Continued. Reference Number
Malay Peninsula, auriferous gravels in..... 659
Malay Peninsula, report for 1904..... 693
Mallet on tin in auriferous gravels in Wicklow, Ireland..... 605
Metallurgy of..... 1204
Mexico, age of deposits..... 783
Mingaye on occurrence in beach sands in New South Wales..... 831
Mining of.....51, 601, 602
Moore on occurrence with tin in killas of St. Pauls Plains, Tasmania. 1114
Napier on sources of gold used by ancients..... 1405
New South Wales, in beach sands with tin....797, 804, 805, 809, 812, 831
Origin of minerals of..... 1206
Queensland 877, 935, 936
Rhodesia 1174
Richthofen on the age of the gold bearing deposits of Mexico..... 783
Rosales on deposits of Mt. Wills, Victoria..... 1234
S. (W. H.) on cassiterite in gold placers of Bear Gulch, South Dakota. 1015
Sadtler on deposits in the Black Hills, South Dakota..... 1016
Separation from platinum, tin, and antimony.....1445, 1455
Separation from platinum, tin, arsenic, and antimony 1474, 1486
Siberia 965
Simmons on deposits in Black Hills, South Dakota..... 1018
Simpson on deposits in Western Australia..... 1267
Skertchly on deposits in Queensland.....935, 936
Smith on tin in gold works in Wicklow County, Ireland..... 607
South Africa 3c
South Australia..... 974
South Dakota.....980, 1015, 1016, 1018
South Dakota, Nigger Hill district, cassiterite in gold placers..... 980
Stephens on tin and gold ores of Pahang, Malay Peninsula..... 728
Tasmania 1072, 1079, 1114
Tasmania, condition of mines in 1904..... 1072
United States..... 1206
Ural (Central Asia), tin said to occur in gold placers..... 40
Victoria, cassiterite in gold placers.....50, 1224, 1225, 1228, 1229, 1234
Voit on deposits of, in South Africa..... 3c
Western Australia.....1259, 1267
Goldmine River, *see* Ireland.
Goldschmidt, K.....1497a
Gongong, *see* China and Malay Peninsula.
Good, T.....1323a
Goonbarrow mine, *see* Cornwall.
Goping, *see* Malay Peninsula, Perak.
Goshen, *see* Massachusetts.
Götting, A..... 259a

Reference Number

Gould, Chas. 1086
de Gouvenain, C. A. 510
Gower, George H. 821, 822, 823, 824
Graham, Walter 1324
Grain tin, preparation of in Cornwall and Devon 1576
Granger, A. 1613
Grant, H. 1087-1091
Graphite, Voit on deposits of, in South Africa 3c
See Association of tin with.
Graphite City, *see* Quebec.
Graton, L. C. 245, 246
Graupen, *see* Bohemia.
Gray, John W. 1325
Great Britain, tin in 1287, 1289, 1290, 1292
Hunt on mineral statistics, 1853–1906 1688
Newland on tin in 1346, 1347
See also England, Ireland, Scotland, and Europe.
Greathead, Samuel 1393
Great Mussel Roe River, *see* Tasmania.
Great Vor district, *see* Cornwall.
Great Work mine, *see* Cornwall.
Greece, Borlase on early tin trade of 1382
Greece, Fischer on crocidolite quartz in 39
Greenbushes, *see* Western Australia.
Greenland, tin in 580
Tin in Laurentian rocks of 224
Allen on minerals in 579
Arsuk (Arsut) Fjord, tin on 583, 584
Boggild on tin in 581
Christianshaabs district, tin in 583
Evigtok near Arksut, tin at 586
Fawns on tin in 1320
Flink on tin in southern part 582
Frederikshaabs, minerals near 580, 583
Giesecke on tin in the Christianshaabs, Frederickshaabs, and Godhavn districts 583
Godhavn district, tin at Itivdliarsuk 583
Hoff on tin at Ivikaet on Arsut Fjord 584
Ivikaet on Arsut Fjord, tin at 584
Rink on the people and products of 585
Tayler on tin at Evigtok near Arksut 586
Greg, R. P., and Lettsom, W. G. 1614
Gregor, William 393, 1498
Gregory, J. W. 1092, 1226

Reference Number

y, T. F.....908, 909
ıstein, *see* Germany.
, H. D..... 1180
s, Harry D.....234, 234a
ck, Albert.....549, 1093
ontein, *see* Transvaal.
lei, *see* Transvaal.
C. de.....101, 130, 131, 132
Joseph..... 772
', J. B. G. A..... 267
', James..... 190
uato, *see* Mexico.
s, Marcel..... 511
er, Richard..... 1326
ro, *see* Mexico.
ne, *see* New South Wales, Bendemeer.
l lodes, *see* New South Wales, Molong district.
lake, *see* Cornwall.
ş Gapis, *see* Malay Peninsula, Telom.
A..... 624
', H. P..... 944

H

P. D..... 1048
e, A. C.....910, 911
oon Bay, *see* New Zealand, Stewart Island.
.. L.....1181, 1182
ch, H.....67, 550
Ed..... 773
on, Alexander..... 294
on, J. H.....695, 696, 697, 1049, 1094
k, Richard..... 394
H. G.....218, 774, 1394
Union mine, *see* Cornwall, Pentuan.
rt-Smith, J.....1095, 1095a
ad, Levy and Ewen on the bessemerizing of.....1521a
ny, Julio..... 1035
' Peak mine, *see* South Dakota.
' Range, *see* South Dakota.
n, G..... 161
Vienne, *see* France.
.....1499, 1615
s, C.....395, 1395
s, John.....396, 397, 398, 399, 1396, 1500

Reference Number

Hayes, Augustus A. 1501
Hazáribágh, *see* India, Chota Nagpur.
Headden, Wm. P. 1008, 1208, 1502, 1616, 1617
Headden, W. P. (Carpenter, F. R., and) 1466
Heale, Josh 875
Heemskirk, *see* Tasmania.
Helfer, J. W. 191
Helmhacker, R. 400
Hematite:
  Beck on occurrence at Schwartzenberg (Germany) 530
  Pirsson on cassiterite crystals in crystals of 1635
  Replaced by cassiterite in Durango, Mexico 771
  See Association of tin with.
Hennecke, Ludwig 864
Henry mine, *see* Tasmania.
Henty, G. M. 401
Henwood, George 402, 403
Henwood, W. J. 404, 405, 406, 407, 408, 1327, 1656
Henz, F. 1503
Henzai, *see* Burmah.
Herberton district, *see* Queensland.
Herman, H. 1227, 1228
Herman, R. 945, 968
Hermann 40
Hersart, Ch. 512
Herter, Paul, and Rath, G. von 625
Hess, Frank L. 26, 27, 247, 1009, 1209–1211, 1328, 1329
Heterosite, *see* Association of tin with.
Heycock, C. T., and Neville, F. H. 1504
Hicks, James 1505, 1657
Hidalgo, *see* Mexico.
Higuei, *see* Santo Domingo.
Hill, J. B. 409, 410
Hill, J. B., and MacAlister, D. A. 411
Hill, J. H. 28
Hin-boun, *see* Siam, Laos.
Hiortdahl, F. H. 1505a
Hirukawa, *see* Japan.
History of tin:
  Alaska 28a
  Baudot on 1378
  Baudot on mines of Villeder, Morbihan, France 498
  Banka 1415
  Banka, history of mining methods 74
  Bapst on antiquity of tin 1375, 1376

History of tin—Continued. Reference Number
Batten on the stannaries act ... 1377
Benedict on tin in California ... 213
Benedict on tin in South Dakota ... 990
Benedict on tin in Tasmania ... 1074
Benedict on tin mining in Cornwall ... 336
Berthelot on minerals and metals of the ancient Chaldeans ... 1379
Bible on tin ... 1380
Billiton ... 134
Boase and Courtney on tin mining in Cornwall and Devon ... 342
Bohemia ... 67, 565, 566, 567
Borlase on early Grecian and Phœnician tin trade ... 1382
Borlase on source of Phœnician tin ... 1381
Borlase on tin in Cornwall ... 1382, 1383
Borlase on tin mining in Spain, past and present ... 1028
Bretherton on tin deposits of Mexico ... 765
Burnard on the antiquity of the Bronze age in Britain and on the laws and customs of the stannaries in Devon ... 1384
California ... 222
Cameron on the Herberton district, Queensland ... 895
Carne on history, ancient methods of mining, and antiquity of diggings in Cornwall ... 354, 355
Chaldeans, tin among the ... 1379
Collett on tin in Malay Peninsula ... 681
Collins on Cornish mines and miners ... 368
Collins on tin production in England ... 1385
Conder on tin mining in Tasmania ... 1078
Conran on tin mining in Cornwall ... 370a
Cornish names, origin of ... 439
Cornwall ... 336, 342, 354, 355, 368, 370a, 412, 413, 427, 439, 450a, 481a, 482, 484, 1382, 1383, 1389, 1395, 1397, 1409, 1419, 1421, 1425, 1426, 1427
Cornwall, Redruth district ... 313
Cornwall tin mining ... 310
Crawfurd on the Indian Archipelago ... 282
D————, C. H., on tin in France ... 1386
Davies on antiquity of tin mining ... 1317
Davy on the antiquity of tin in Great Britain ... 1387
Devon ... 342, 413, 1384, 1419, 1425, 1426, 1427
Dufrené on the production and commerce of tin ... 1388
East Indies ... 305
Edmonds on Phœnician tin trade with Cornwall ... 1389
Egyptians, tin among the ... 1392, 1424
England ... 415, 1384, 1385, 1387, 1395, 1396, 1402, 1403, 1404, 1407, 1413, 1417
Fawns on ... 1320

History of tin—Continued. Reference Number
Feuchtwanger on ... 1321
Flower on the tin plate trade ... 1390
France ... 498, 1386, 1406, 1416
Freiesleben on the mines of Germany ... 547
Furman on discovery of tin in North Carolina ... 242, 242a
Garrison on tin in the United States ... 1207
Gatzschman on tin mining at Freiberg, Saxony ... 1391
George on mining and use of metals by Egyptians ... 1392
Germany ... 547, 550, 564, 570, 571
Grant on Tasmanian tin deposits ... 1086
Greathead on sources and uses of tin among ancients ... 1393
Grecians, tin among the ... 1382
Hallwich on mining at Graupen and Upper Graupen, Bohemia ... 67, 550
Hamilton on discovery of tin in Sumatra ... 294
Hanks on discovery of tin ... 1394
Hawkins on ancient tin trade in Cornwall ... 1395
On tin mines of England ... 1395, 1396
Headden on discovery of tin in Black Hills, South Dakota ... 1008
Hill on York tin mines, Seward Peninsula, Alaska ... 28a
Hunt on British mining ... 415
On tin trade in Cornwall and Devon ... 412
On tin and copper production in Cornwall ... 412
On traditions and history of Cornish tin mining ... 1397
Indian Archipelago ... 282
Ireland ... 603
Italy, discovery of tin, and antiquity of bronze in ... 611
James on the Ictis of Diodorus ... 1398
On Phœnician tin trade ... 1399
Kayser on tin mining in Tasmania ... 1100
Kenrick on Phœnician tin trade ... 1400
Kinahan on antiquity of tin in Ireland ... 603
Lakes on history, uses, and sources of tin ... 1334a
Lewis on the English tin miner ... 1402
Lewis on sources of Phœnician tin ... 1401
Louis on ... 1340
MacAlister on Cornish mines ... 427
Maclean on the stannary roll ... 1403
Maclean on tin coined in England between 1305 and 1607 ... 1404
Malay Peninsula ... 681, 747
Mexico ... 765
Missouri ... 1423
New South Wales, discovery of tin in ... 798, 802
North Carolina ... 237, 242
Napier on sources of ancient tin ... 1405
Paris on origin of Cornish names, etc ... 439

History of tin—Continued. Reference Number
Pattison on antiquity of tin in France..... 1406
Pearce on ancient tin blocks found in Fowey Harbor..... 1407
Phœnicians.....744, 1381, 1382, 1389, 1399, 1400, 1401, 1410, 1414, 1418
Plinius on ancient tin..... 1408
Polwhele on tin in Cornwall..... 1409
Posewitz on discovery of tin in Billiton..... 134
Praagh on discovery of tin in Transvaal..... 1186
Queensland 895, 934
Ranft on Mt. Bischoff mine, Tasmania..... 1122
Rawlinson on Phœnician tin trade..... 1410
Reyer on..... 1412
On different tin regions..... 1354
On the tin-bearing rocks and tin works in the Erzgebirge, Germany 564
On tin between 1800 B. C. and A. D. 1873..... 1411
On tin mining in Bohemia and Saxony.....565, 566
Rhys on early Britain, Celtic Britain..... 1413
Rickard on "Fifty years in Cornwall"..... 450a
Rolker on tin mining in the East Indies..... 305
Saunders on sources of Phœnician tin..... 1414
Saxony 565, 566, 567, 1391
Schmidt on tin in the Fichtelgebirge.....570, 571
Schultz on history of the use of tin..... 1359
Schuurman on tin in Banka..... 1415
Simmons on tin in the Black Hills..... 1019a
Simonin on tin mines in Brittany..... 1416
Skertchly on the Herberton district, Queensland..... 934
Smirke on tin trade between Britain and Alexandria in 17th century, 1417
Smith on source of early Phœnician tin..... 1418
South Dakota.....990, 1008, 1019a, 1192
Spain 1028
Stevens on..... 1363
Sumatra 294
Tasmania.....1074, 1078, 1086, 1100, 1122, 1158a
Taylor on "Iktis" and on copper, iron, and tin..... 1420
Taylor on mining in Cornwall and Devon..... 1419
Transvaal 1186
United States 1207
Vivian on tin and copper mining in Cornwall..... 481a
Wait on history of tin in Cornwall..... 482
Ward on tin field of North Dundas, Tasmania..... 1158a
Warner on tin in Cornwall..... 1421
Webb and Geach on Caradon and Liskeard district of Cornwall..... 484
Weeks on..... 1372
Werner on the most ancient metal..... 1422

History of tin—Continued. Reference Number
West on Temescal mines, California ... 222
Wheeler on tin mining fraud in Missouri ... 1423
Winer on metals and minerals of ancient Egypt ... 1424
Worth on tin mining in Cornwall and Devon ... 1425, 1426, 1427
Wray on Malayan tin trade ... 747
On source of early Phœnician tin ... 744
See references Nos. 1373–1427.
Hitachi, *see* Japan.
Hitchcock, C. H. ... 649, 650
Hitchcock, Edward ... 749
Hoang-hai, *see* Korea.
Hochstetter, Ferdinand ... 294, 295
Hoff, Th. ... 584
Hoffman, G. C. ... 228
Hoffman, W. J. ... 788
Hofman, Heinrich O. ... 1506
Hohagen, Georg ... 1506a
Holland, T. H. ... 192, 591
Honduras, Montis on tin in ... 586a
Hoogekrall, *see* Cape Colony.
Hooze, J. A. ... 102
Hopkins, Evan ... 1330
Hopkinson River, *see* Queensland.
Hornblende, *see* Association of tin with.
Horsfield, Thomas ... 103
Horsley, Sydney ... 912
Hosainpura, *see* India, Palanpur.
Hoskold, H. D. ... 38
Howell, *see* New South Wales.
Huaina, *see* Bolivia, Juaina Potosi.
Huancane, *see* Peru, Puno.
Huanuna, *see* Bolivia, Juanuni district.
Huanuni, *see* Bolivia, Juanuni district.
Huaina, *see* Bolivia, Juaina Potosi.
Huayna, *see* Bolivia, Juaina Potosi.
Hübnerite, *see* Association of tin with.
Huel Bijjerkerno mine, *see* New South Wales.
Huel Peever mines, *see* Cornwall.
Huel Wherry mine, *see* Cornwall.
Hughes, T. W. H. ... 193, 194, 1507
Hughes Creek, *see* Idaho.
Huguenin, J. A. ... 104
Hulseite, Knopf on a new magnesian iron-tin boron mineral ... 29a, 29b
Humbolt, Alexander de ... 775
Hume, W. C. ... 913
Hume, W. J. P., and Dykes, F. J. B. ... 698

Reference Number

Hungary, Phillips and Louis on tin in..... 1350
Hunt, John.....1096, 1097
Hunt, Robert 412, 413, 414, 415, 1397, 1619, 1687, 1688
Hunt, T. Sterry.....651, 652, 1331
Huoyna, *see* Bolivia, Juaina Potosi.
Hutchin, H. W.....1507a, 1507b
Hutchinson, A..... 1620
Hyûga, *see* Japan.

I

Iberian Peninsula, Louis on tin in..... 1340
Ichoca, *see* Bolivia.
Ictis of Diodorus Siculus, Hawkins on the..... 1395
James on the..... 1398
Tylor on the..... 1420
Idaho, Bitter Root Mountains, tin in drainage from.....214, 1201
Blake on tin in streams flowing from Bitter Root Range.....214, 1201
Blake on tin in..... 1202
Kemp on tin in 1213
Lindgren on wood tin on Hughes Creek..... 586b
See also United States.
Iktin, origin of name..... 1389
Ilmenite, *see* Association of tin with.
Impact screen, used at Wheal Kitty, Cornwall..... 1652
Importation of tin:
Russia, 1888–1890 941
Russia, 1904 942
Victoria, 1899 to date..... 1222
India:
Ball on tin in..... 589
Bastar, tin in..... 597
Bengal, tin in.....596, 597
Bombay, tin in..... 597
Chota Nagpur, tin in.....588, 592, 593, 595, 596, 597
Hazáribágh district, tin in.....588, 593, 595
Nurgo or Nurunga (Narungo), tin at.....592, 596
Pihra, tin at.....592, 593
Simratari, tin at.....592, 593
D'Achiardi on tin in..... 1313
Fermor on the manganese ore deposits of..... 590a
Garhval, tin in..... 598
Holland on tin at Hosainpura in Palanpur..... 591
King on tin from several places in Chota Nagpur..... 592
Kumaon, tin in..... 598
Lock on tin in..... 1338
Louis (Phillips and) on tin in..... 1350

India—Continued. Reference Number
Mallet on tin in ... 594
Mallet on tin in Hazáribágh, Pihra, and Simratari ... 593
Martaban, tin in ... 595
Medlicott on tin in Hazaribagh and Martaban ... 595
Oates on tin at Narungo, near Baragunda, Bengal ... 596
Palanpur, Hosainpura, tin at ... 587, 591
Phillips and Louis on tin in ... 1350
Rudra on tin in Bengal, Chota Nagpur, Bombay, and Bastar ... 597
Stephens on tin in Kumaon and Garhval ... 598
See also Burmah and Asia.
Indium, *see* Association of tin with.
Indo China, tin in ... 265
Indo China, *see* also Malay Peninsula, Siam, and Laos.
Induwehena, *see* Ceylon.
Ingalls, Walter Renton ... 229, 776, 777, 778, 1332
Ingoda River, *see* Siberia.
Inverell district, *see* New South Wales.
Inyo County, *see* California.
Iodide of tin, Hunt on influence of magnetism and voltaic electricity on crystallization of ... 1619
Iodine, Personne on the combination of tin and ... 1550
Ireland, Mark ... 1098
Ireland:
Ballinvally, tin at ... 601
Coolbawn, tin in ... 601
Cork, Kilcrohane (Sheep Head), tin at ... 602
Croaghan Mountains, tin in ... 607
Dublin, geology near ... 600, 602, 609
Dalkey at Kingstown, lode tin at ... 602, 603
Fawns on tin in ... 1320
Fitton on geology near Dublin and on tin at Wicklow ... 600
Goldmine River, tin on ... 428
Henwood on tin and gold in Wicklow ... 1327
Hunt on mineral statistics, 1853–1906 ... 1688
Kerry, Killarney, tin at ... 602, 603
Kerry, Lough Leane, tin at ... 602
Kinahan on tin at Ballinvally, Monaglogh, and Coolbawn ... 601
On tin in Dublin, Kerry, Cork, and Wicklow ... 602, 603
Maclaren on tin in Wicklow ... 604
On gold and tin on Goldmine River, Wicklow County ... 428
Mallet on tin in Wicklow ... 605
Monaglogh, tin in ... 601
Mourne Mountains, tin in ... 603, 606
Seymour on tin in the Mourne Mountains ... 606

Ireland—Continued. Reference Number
Smith on tin in the Croaghan Mountains, Wicklow..... 607
Weaver on tin at Croghan Kinshela, Wicklow..... 608
On tin in Dublin and Wicklow..... 609
Wicklow, tin in.....599, 600, 602, 603, 604, 605, 607, 608, 609, 1327
Croaghan Mountains, tin in..... 607
Croghan Kinshelagh area, tin in.....604, 608
Goldmine River, Woodenbridge, tin in.....602, 603
Ovoca district, tin in..... 603
See also Great Britain and Europe.
Irish Creek, *see* Virginia, Rockbridge County.
Iron:
Alloys with tin and other metals.....1452, 1502
As an element, an ore, in manufacture, in commerce, and in history. 793
Associated with tin, *see* Association of tin with iron and the different iron minerals.
Billings on alloys with tin and other metals..... 1452
Billiton 126a
Bolivia 155
Burmah, Tenasserim..... 191
Campagne on mines of..... 1309
China 267
Commerce of..... 793
Cornwall 455, 1617
Earliest production of..... 1420
Egypt (B.C. 3124)..... 1420
Emmons on occurrence in United States and genesis of minerals of.. 1206
Finland, Pitkäranta..... 953a
Foniakoff on deposits in Siberia..... 965
Friesleben on deposits near Breitenbrunn, Germany..... 546
Furnaces, forges, and rolling mills of the United States..... 793
Germany, Breitenbrunn..... 546
Greenland 580
Grosier on, in China..... 267
Headden on alloys of tin and iron, etc..... 1502
Headden on iron compounds in an old Cornwall furnace..... 1617
Helfer on iron in Tenasserim district of Burmah..... 191
Hennecke on occurrence in Persia..... 864
History of..... 793
Hydrolysis of salts of, in presence of iodides and iodates..... 1537
Lesley on furnaces, forges, and rolling mills of the United States.... 793
Manufacture of..... 793
Mines of..... 1309
Moody on hydrolysis of salts of, in presence of iodides and iodates. 1537
Pilz on deposits in Cartagena, Spain..... 1040

Iron—Continued. Reference Number
Pearce on separation from tin ore ... 1547
Persia ... 864
Separation from tin ore ... 1547
Siberia ... 965
Simmons on occurrence of ores of, in Cornwall ... 455
South Africa ... 3c
Spain, Cartagena ... 1040
Sulphides of, associated with tin in Bolivia ... 155
Tasmania ... 1079
Tylor on earliest production of iron, copper, and tin ... 1420
Trüstedt on iron ore deposits at Pitkäranta, Finland ... 953a
United States ... 793
Vöit on deposits of in South Africa ... 3c
Iron arsenate, *see* Association of tin with.
Iron oxide, *see* Association of tin with.
Iron pyrite, *see* Association of tin with.
Iron sulphides, *see* Association of tin with.
Irvinebank, *see* Queensland.
Irving, J. D. ... 1010, 1011
Italy:
Beco and Thonard on tin in Tuscany ... 612
Berget on tin in Campiglia Marittima, Tuscany ... 613
Blanchard on tin in Campiglia Marittima, Tuscany ... 614, 615, 616
Braun on tin in ... 617
Brown on tin in ... 1307, 1308
Caillaux on tin in Tuscany ... 618
Charlon on tin in Tuscany ... 619
Church on tin in ... 620
D'Achiardi on tin in ... 1313
On tin in Campiglia Marittima, Tuscany ... 621
Dalmer on tin in Campiglia, Tuscany ... 622
Ernst on tin in ... 623
Fawns on tin in ... 1320
Fuchs and de Launay on tin in ... 1323
Gurit on tin on Monte Fumachhio near Campiglia, Tuscany ... 624
Herter and Rath on tin in Campiglia ... 625
Langer on tin in Tuscany ... 626
de Lapparent on tin in ... 1335
de Launay (Fuchs and) on tin in ... 1323
Lotti on tin in Campiglia, Tuscany ... 627
Phillips on tin in Campiglia Marittima, Tuscany ... 628
Phillips and Louis on tin in ... 1350
Rath (Herter and) on tin in Campiglia, Tuscany ... 625
Thonard (Beco and) on tin in Tuscany ... 612

Italy—Continued. Reference Number
Tuscany, tin in....612, 618, 626, 627a
Beck on tin on Elba 1300
Boceheggiano, tin in copper ores of.... 613
Campo Alle Buche, tin at.... 627
Campiglia, tin near..610, 613, 614, 615, 616, 621, 622, 624, 625, 627, 628
Cento Camerelle, tin in the....615, 621, 627
Elba, tin on 1300
Massa Marittima, tin in copper ores of.... 613
Monte Calvi, tin near 613
Monte Fumachhio, tin on....613, 615, 624
Monte Valerio, tin on 613, 627
See also Europe.
Itivdliarsuk, *see* Greenland, Godhavn district.
Ivikaet, *see* Greenland.

J

Jack, Robt. L....914–918
Jackson, Ch. T....653, 654, 791, 792
Jackson [J. R.?].... 219
Jackson, *see* New Hampshire.
Jacobs, E. 28b
Jaquet, J. B.... 825
Jahor, *see* Malay Peninsula, Johore.
Jalar, *see* Siam.
Jalisco, *see* Mexico.
James, Henry....1398, 1399
Jameson, Robert.... 1621
Japan, tin in....629, 1672
Beck on tin in 1299
Bungo, tin in 631, 632, 636
Kiura mine, tin in the.... 630
Ohira-tetsu-san, tin in.... 634
D'Achiardi on tin in.... 1313
Fawns on tin in 1320
Godfrey on tin in Bungo and Taniyama, Satsuma.... 631
Hirukawa, stream tin near.... 630
Hitachi, tin in....632, 636
Hyūga, tin in.... 636
Jimbo on tin in Mino, Satsuma, Bungo, and Hitachi.... 632
Kinshin Island, tin on.... 634
Munroe on tin in, especially Taniyama mine.... 633
Mino, tin in....632, 636
Rein on tin in Satsuma and Bungo.... 634
Rolker on tin in....1357

Japan—Continued. Reference Number
Satsuma, tin in 632, 636
Taniyama, tin in 631, 633, 634, 635
Suo, tin in 636
Takayama, stream tin near 630
Wada on tin industry, 1867–1892 635
See also Asia.
Jars, G. 416, 1333
Java, Cretier on tin at Batavia 283
See also East Indies.
Jelebu, *see* Malay Peninsula.
Jenisei region, *see* Siberia.
Jeremejev, P. 1622, 1623
Jerusalem Creek, *see* New South Wales, Richmond County.
"Jew's House," Le Grice on at Trereife, near Penzance, Cornwall 1518
Jigs used in manipulation of tin and copper ores in Cornwall 1656
Jimbo, Kotora 632
Joachimsthal, *see* Bohemia.
Johanngeorgenstadt, *see* Saxony.
Johnson, J. B. 1183
Johnson, J. C. F. 51
Johnson, J. P. 2a
Johnston, R. W. 1099
Johore, *see* Malay Peninsula.
Jokèly, Joh. 68
Jolyet, F., and Cahours, A. 1508
de Jongh, D. 105, 106, 107
de Jongh, H. D. 108
Jorissen, E. 1050
Josephats Valley, *see* Malay Peninsula.
Juaina Potosi, *see* Bolivia.
Juanuni district, *see* Bolivia.
Juncker (Dufrénoy, P. A., and) 507
Juncker and Dufrénoy, P. A. 513
Junk-Ceylon, *see* Siam.
Juwaa, *see* Persia.

K

K————, W. 417
de Kalb, Courtnay 1334
Kamerun:
Tin in 637, 638
Fawns on tin in 1320
Macco on tin in 639
See also Africa.
Kammun, *see* Siam, Laos.

Reference Number

Kampar River, *see* Malay Peninsula, Perak.
Kamunting, *see* Malay Peninsula, Perak.
Kandawangan, *see* Borneo.
Kangaroo Hills, *see* Queensland.
Kaolin:
Hennecke on occurrence in Persia..... 864
See Association of tin with.
Karimata, *see* East Indies.
Karimon Island, *see* East Indies.
Karlsbad, *see* Bohemia.
Katanga, *see* Kongo.
Kayser, H. W., and Provis, Richard..... 1102
Kayser, H. W. F.....1100, 1101
Kedah, *see* Siam.
Kelantan, *see* Siam.
Kemaman, *see* Malay Peninsula.
Kemp, Jas. F.....1212, 1213
Kempen, A. R. (Brandenburg, H., Weyland, A., and)..... 1456
Kempton, C. W..... 779
Kendrick, John..... 1400
Kenngott, A..... 1509
de Keppen, A.....946, 969
Kerforne, F..... 514
Kerl, Bruno.....418, 419, 1510
Kerndt, C. H. Thdr..... 515
Kerry, *see* Ireland.
Kershaw, John B. C.....1511, 1511a
Kersten, C. M..... 1512
Keweenaw County, *see* Michigan.
Keyzer, S. S..... 235
Kieves, used in Cornwall..... 1656
Kilcrohane (Sheep Head), *see* Ireland, Cork.
Killarney, *see* Ireland, Kerry.
Kinahan, G. H.....601, 602, 603
Kinebetungen River, *see* Borneo.
King, W..... 592
King, Will..... 195
King Conrad, *see* New South Wales, Howell.
King of the Ranges, *see* Queensland, Watsonville.
Kingsgate, *see* New South Wales.
Kings Mountain, *see* North Carolina.
Kingston, *see* Ireland, Dublin.
Kinshin Island, *see* Japan.
Kinta, *see* Malay Peninsula.
Kitson, A. E..... 1229

Reference Number

Kitto, Benedict 420
Kiura mine, *see* Japan, Bungo.
Kjerulf, Th., and Brögger, W. C. 826
Klaproth, Martin H. 1513
Kledang Range, *see* Malay Peninsula.
Klipstein, A. 551
Klockmann, F. 1103
Klondike River, *see* Yukon.
Knight, Enoch 220
Knopf, Adolph 29, 29a, 29b
Koba district, *see* Banka.
Koetong, *see* South Australia.
Kogin-Delume River, *see* Nigeria, Gimpy River.
Kohlmann, W. 1624
Kongo, tin in 1287
  Buttgenbach on tin in 273
    On tin in Katanga 274, 275
  Farrell on copper and tin in Katanga 276
  Fawns on tin in 1320
    On tin in Katanga 277
  Katanga, tin in 274, 275, 276, 277
    Busanga mine, tin in 277
    Copper and tin in 276
    Lualaba River, tin near 274, 276, 277
    Lufira River, tin near 276
  Lacroix on tin in 278, 516
  See also French Kongo and Africa.
de Koninch, L. L., and Lecrenier, A. 1474
Koorboora district, *see* Queensland.
Koperberg, M. 296
Korea:
  Fawns on tin in 1320
  Oppert on tin in Hoang-hai 640
  See also Asia.
Korzoukhine, J. A. 970
Kotchiou, *see* China, Yunnan.
Kotiou *see* China, Yunnan.
Koulibine, S. 1690, 1691, 1692
Kra (West Coast), *see* Siam.
Krusch, P. 947, 1257, 1258
Kuala Diepang, *see* Malay Peninsula, Perak.
Kuala Lumpur, *see* Malay Peninsula.
Kuantan, *see* Malay Peninsula, Pahang.
Kuchai, *see* Malay Peninsula, Selangor.
Kuils River, *see* Cape Colony.
Kumaon, *see* India.

Reference Number

Kundernatsch, Joseph 421
Kunhardt, Wheaton B. 1658
Künzel, C 1514
Kuochinchang, *see* China.
Kuruwita, *see* Ceylon.
Kynaston, H 1183a, 1183b

L

La Bianca, *see* Bolivia.
La Bolivinia mine, *see* Bolivia.
Lacroix, A. 278, 516, 644
Ladock, *see* Cornwall.
Lagos, *see* Mexico.
Lahat, *see* Malay Peninsula, Perak.
Lake Loadut, *see* Burmah, Tenasserim.
Lakes, Arthur 1169a, 1334a
Lakon, *see* Siam.
Lampadius, W. A. 1515, 1516
Landon, J. (Maier, P. J., and) 133
Lands End district, *see* Cornwall.
Lange 109
Langer, J. H. 626
Laos, *see* Siam.
Lapage, Herbert 1259
LaPaz, *see* Bolivia.
La Poma district, *see* Argentina, Salta.
de Lapparent, A. 1335
Laroot, *see* Malay Peninsula, Larut.
Larrouy 867
Larut, *see* Malay Peninsula.
Las Cuevas, *see* Mexico.
Lassalle, Th. 517
Latrobe River, *see* Victoria, Gippsland.
Latta, Geo. J. 1517
Laube, Gustav C. 69
de Launay, L. 3, 518, 854, 1625
de Launay, L. (Fuchs, E., and) 66, 159, 509, 1323
Launceston, *see* Tasmania.
La Unificada mine, *see* Bolivia.
Lawn 1183c
Lawrence County, *see* South Dakota.
Lead:
  Allen on alloy with copper and manganese 1431
  Alloys with copper and manganese 1431
  Alloys with tin 1545a, 1548, 1552

Lead—Continued. Reference Number
Alloys with antimony 1552
Alloys with zinc and tin 1570, 1587
Associated with tin, *see* Association of tin with.
Argentina, Salta 37
Betts on completely removing tin in process of refining lead 1451
Billiton 126a
Bohemia, Graupen 542
Bolivia 155
Campagne on mines of 1309
Castro on, in Salta, Argentina 37
China 267
Composition of refined lead 231
Cornwall 455
Dalmer on origin of ores in Altenberg-Graupen district of Saxony and Bohemia 542
Dalmer on presence in cobalt district of Schneeberg, Saxony 543
Douglas on metallurgy of 1204
Dumble on tin in lead ores in Texas 1169
Emmons on occurrence in United States and genesis of minerals of. 1206
Foniakoff on deposits in Siberia 965
Great Britain 444
Grosier on, in China 267
Hermann on lead in metallic tin in gold washings of the Ural (Central Asia) 40
Ireland 602
Johnson on origin of deposits in South Africa 1183
Kinahan on, in Ireland 602
Korea, Hoang-hai 640
Menniche on separation of from tin ores 1534
Metallurgy 444, 1204
Oppert on, in Hoang-hai, Korea 640
Origin of minerals of 1206
Origin of ores 542, 575, 1183
Parry on the eutectic alloy of tin and 1545a
Peetz on separation of tin and lead in tin-lead alloys 1548
Pilz on deposits in Cartagena, Spain 1040
Plattner on alloys of tin and antimony with lead at Freiberg, Saxony. 1552
Pryce on mining and metallurgy of in Great Britain 444
Richter on characteristics and working, and on relations with zinc and tin 1356
Saxony:
Altenberg 542
Freiberg 575, 1552
Schneeberg 543
Schultz on production and application of solder 1359

Lead—Continued. Reference Number
Separation from tin....1534, 1548
Siberia 965
Simmons on occurrence of ores of, in Cornwall.... 455
Slater on alloys of zinc, tin, and lead 1570
Solder 1359
South Africa.... 1183
Spain, Cartagena.... 1040
Stelzner on origin of ores at Freiberg, Saxony.... 575
Sulphides of, associated with tin in Bolivia 155
Tasmania 1079
Texas 1169
United States.... 1206
Ural (Central Asia), with metallic tin 40
Wolf on composition of refined lead.... 231
World statistics since 1890.... 1694
Wright on alloys of zinc, lead, and tin at low and high temepratures. 1587
Lead carbonate, *see* Association of tin with.
Lead sulphide, *see* Association of tin with.
Leadville, *see* Colorado.
Leane, *see* Ireland, Kerry, Lough Leane.
Leclere, A.... 268
Lecrenier, A. (de Koninch, L. L., and).... 1474
Ledoux, Albert R.... 248
Le Grice, C. V.... 1518
Leibius, Adolph.... 1336
Leier mine, *see* Saxony.
Leifchild, John R.... 422
Lemon, Chas., and Tremenheere, G. B.... 196
Leonhard, Gustav.... 1214
Lepidolite, *see* Association of tin with.
Lepsius, Richard.... 551a
Lesley, J. P.... 793
Lettsom, W. G. (Greg, R. P., and).... 1614
Levant, *see* Cornwall.
Levol, A....1519-1521
Levy, D. M., and Ewen, D....1521a
Lévy, Michel (Fouqué, F., and).... 1610
Lewy, B.... 1522
Lewis, George Cornewall.... 1401
Lewis, George Randall.... 1402
Lewis, James B....1104, 1105, 1106
Lias, tin at contact between tourmaline granite and linestones of Lias age in Tuscany....610, 613, 615, 627, 628
Limonite, *see* Association of tin with.
Limousin, *see* France.

Reference Number

de Limur (le Comte) 519
Lindgren, Waldemar 586b, 1337
Lingngan-fu, *see* China, Yunnan.
Lington, T. 422a
Lions Den, *see* Queensland.
Liskeard, *see* Cornwall.
Lithia mica, *see* Association of tin with.
Little Usutu River, *see* Transvaal.
Liversidge, Archibald 827, 828, 829, 830
Lizolle, *see* France, Allier.
Llallagua vein, *see* Bolivia.
Llano County, *see* Texas.
Loadut (Lake), *see* Burmah, Tenasserim district.
Lobley, J. Logan 423
Lock, C. G. Warnford 197, 424, 699, 700, 701, 1338
Lodin 520, 521
Loire Inferieure, *see* France, Lower Loire.
de Loos, D. 1339
Los Angeles, *see* California.
Lost River, *see* Alaska.
Lotti, B. 627
Lough Leane, *see* Ireland, Kerry.
Louis, Henry 702, 703, 1340, 1523-1527
Louis, H. (Phillips, J. A., and) 628, 1350
Low, James 704
Lower, T., *see* No. 489a.
Lower Loire, *see* France.
Lowig 1528
Lozére, *see* France.
Lozano, R. Sanchez 1036
Lualaba, *see* Rhodesia.
Lualaba River, *see* Kongo, Katanga.
Lufira River, *see* Kongo, Katanga.
Lunenberg County, *see* Nova Scotia.
Lusitania, Plinius on "white lead" from 1408
Luxer, *see* Bohemia, Graupen.
Lyburn, John 1051

M

M————, H. 1012
MacAlister, Donald A. 426, 427, 449, 1341, 1659, 1693
MacAlister, D. A. (Hill, J. B., and) 411
MacAlister, D. A. (Ussher, W. A. E., and) 481
Macco, A. 639
Macdonald, A. R. 919-923, 924
Machi, *see* Malay Peninsula.

Reference Number

Mackenzie, Geo. L. 1529
Mackintosh River, *see* Tasmania.
Maclaren, J. Malcolm 428, 604, 925
Maclean, John 1403, 1404
Mactear, Jas. 865
Madagascar, Ambatofangehana, tin in 648
Ambohimanga, tin in 648
Antananarivo, tin from 647
Bouse on the mineral and other resources of 646
Dunstan on tin from Antananarivo 647
Lacroix on tin in 516
Pelatan on tin near Ambatofangehana and in Ambohimanga 648
Madison County, *see* Missouri.
Magnesite, Voit on deposits of in South Africa 3c
Magnetite:
Beck on occurrence at Schwartzenberg, Germany 530
See Association of tin with.
Maier, P. J., and Laudon, J. 133
Maine:
Day on tin in 1203a
Hebron, tin at 1331
Hitchcock on tin at Winslow 650
On tin at Mt. Mica and Mt. Rubellite 649
Hunt on tin in 651, 652
On tin ore at Winslow, Paris, and Hebron 1331
Jackson on tin in 653
On tin at Winslow 654
Kemp on tin in 1213
Mount Mica, tin in 649
Mount Rubellite, tin in 649
Paris, tin at 1331
Rolker on tin in 1357
Winslow, tin at 650, 651, 652, 654, 1331
See also United States.
Maine-et-Loire, *see* France.
Maitland, A. Gibb 926, 1260-1264
Majendie, Ashurst 1342
Malacca, *see* Malay Peninsula.
Malachite, *see* Association of tin with.
Malaken, *see* China, Yunnan.
Malay Archipelago, Garrison on tin in 1207
Louis on tin in 1340
Malay Peninsula, tin in 676a, 1284, 1290, 1292, 1298
Ayer Dangsang, tin and other minerals at 726, 726a
Ayer Panas, tin in siliceous sinter from 726b

Malay Peninsula—Continued. Reference Number
Balfour on tin in ... 677
Becher on tin mining in ... 678
Beck on tin in ... 1299
Benedict on tin in ... 1301
On tin in Perak ... 679
Brown on tin in ... 1307, 1308
Bruseh, tin at ... 726
Bundi, adobe furnaces and slags from old tin mines at ... 1468
Tin in ... 659, 726, 726b
Changkat Pari, tin at ... 726
Clifford on tin in ... 680
Collett on tin in ... 681
Collins on adobe furnaces and slags from old tin mines at Bundi ... 1468
Cornubian on lode mines of Pahang ... 681a
Cramer on tin in Malacca ... 682
Croockewit on tin in Malacca ... 683
D'Achiardi on tin in ... 1313
Davies on tin in ... 1317
De La Croix on tin in Perak ... 684, 685, 686
Derrick on tin mines of Kuantan, Pahang ... 687
Dijk on tin in Larut ... 690
Doyle on tin in ... 689
On tin mining in Larut ... 688
Dykes on tin in ... 691, 693
Dykes on tin in Perak ... 692
(Hume and) on tin in Perak ... 698
Ellis (McKillop and) on tin in Pulo Brani, Singapore ... 1530
Fawns on tin in ... 1320
On tin in Tringganu ... 694
Flower-Ellis on geology of, occurrence of tin ore in, valuation of tin in, and mining and smelting of tin in ... 1489
On the Malay tin industry ... 694a
Fuchs and de Launay on tin in ... 1323
Gongong, tin at ... 742, *see* also No. 261
Hamilton on tin in Perak, Selangor, and Parcelore ... 294
Hampton on tin in ... 697
On tin in Perak ... 696
On tin in Straits Settlements ... 695
Hughes on tin smelting and furnaces in Singapore ... 1507
Hume and Dykes on tin in Perak ... 698
Jelebu, Sungei Riu, tin at ... 659
Johore, tin in ... 308, 710, 742
Muntaha, tin deposits of ... 741
Josephats Valley, tin in ... 726
Kledang Range, mineral veins in the ... 726a

Malay Peninsula—Continued. Reference Number
Kemaman, tin in....726, 726b
Kinta districts, tin in....714, 715, 717, 721
Kuala Lumpur, tin at.... 740
Lakes on tin in.... 694
Laroot, *see* Larut.
Larut, tin at.... 740
Tin mining in....688, 690, 717
de Launay (Fuchs and) on tin in.... 1323
Lock on tin in.... 701
On tin in Tringganu....699, 700
Louis on tin in....702, 1340
On tin in Malacca.... 703
Louis (Phillips and) on tin in 1350
Low on tin in countries lying between Malay Peninsula and 18° North Latitude.... 704
Machi tin field.... 726
Malacca, tin in....299, 303, 304, 682, 683, 703, 740, 744
(Chin Chin and Tanjong Serai), tin in.... 726
Earl of Mount Edgcumbe on tin produced in 1883.... 1681
Sungie Ujong.... 299
Marks on tin mining in.... 704a
McKillop and Ellis on tin smelting in Pulo Brani, Singapore.... 1530
Meunier on tin in Selangor.... 705
Miles on dredging in Tongkah harbor.... 705a
Morgan on tin in Perak.... 706
Moss on tin in Perak.... 707
Negri Sembilan, tin in.... 667
Newbold on tin in Sunjie Ujong in the interior of Malacca.... 299
Newland on tin in....708, 1346, 1347
Noyes on tin in Serendah Valley, Selangor.... 709
Osbeck on tin from Pegu and Jahor.... 710
Owen on tin in.... 712
Owen on tin in Perak.... 711
Pahang, lode mines of.... 681a
Scheelite in tin deposits at.... 726a
Pahang, tin in....659, 663, 667, 673, 674, 687, 697, 728, 736
Kuantan, tin at....659, 663, 687
Kuantan (Sungei Lembing), tin of.... 726
Parcelore, tin in.... 294
Parkes on tin mining in.... 713
Pegu, tin from.... 710
Penrose on tin in the Kinta districts.... 714
Perak, tin in....294, 304, 658, 660, 667, 670, 679, 684, 685, 686, 691, 692, 696, 698, 706, 707, 711, 715, 731, 732, 735, 737, 747
Assam Kumbang, tin at.... 737

Malay Peninsula: Perak—Continued. Reference Number
Dindings, tin at ... 737
Goping, tin at ... 737
Kampar River, tin at ... 737
Kamunting, tin at ... 737
Kuala Diepang, tin at ... 737
Lahat, cassiterite with tremolite at ... 726a
Lahat, tin at ... 737
Miners, their mode of living, prosperity, etc ... 686, 688
Pappan, tin at ... 737
Poussin, tin at ... 737
Salak, scheelite deposits at ... 726a
Salak, tin at ... 737
Selama, tin at ... 737
Sungei Bâtang Pâdang district, tin in ... 684
Sungei Besi, tin of ... 726
Sungei Bidor district, tin in ... 684
Sungei Kinta district, tin in ... 684
Taiping, tin near ... 723, 737
Tambun mine ... 670, 691
Tecca, tin at ... 737
Thaiping, *see* Taiping.
Tronoh, tin of ... 691, 726
Phillips and Louis on tin in ... 1350
Pike on tin in Kinta and Perak ... 715
Place on tin in ... 716
Qualla Lumpor, *see* Kuala Lumpur.
Rathborne on labor, mines, roads, fuels, economic conditions, etc., in ... 717
Reyer on tin in Malacca ... 303, 304
On tin in Perak ... 304
Ritter on tin in ... 718
Rolker on tin in ... 1357
Rumbold on tin deposits of Kinta Valley ... 721
Saunders on tin in Straits Settlements ... 722
Scrivenor on origin of tin deposits, with special reference to those of Malay Peninsula ... 726b
On tin in ... 724, 725, 726
On tin near Taiping, Perak ... 723
Selangor, tin in ... 294, 659, 667, 705, 709
Kuchai, tin at ... 659
Serendah Valley, tin in ... 709
Meunier on tin oxide in geyserite (?) in ... 705
Sexton on smelting methods at Singapore ... 1361, 1507, 1530
Singapore, McKillop and Ellis on tin smelting at Pulo Brani ... 1530
Sexton on smelting methods at ... 1361, 1507, 1530
Slack on a handbook of the mining companies in ... 727
Slack on tin in ... 727

Malay Peninsula—Continued. Reference Number
Stephens on tin at Pahang ... 728
Stokes on tin in ... 729
Stokes on tin in British Empire ... 730
Subsidence in of recent date ... 717
Swettenham on tin in Perak ... 731, 732
Tanjong Malim, tin at ... 726
Taylor on tin in ... 733
Telom district (Tras, Bentong, Gunong Gapis, Bukit, and Fraser) ... 726
Tenison-Woods on tin in ... 734, 735
On tin in Pahang ... 736
On tin in Perak ... 735, 737
Tonghah Harbor, dredging for tin in ... 676, 676a, 705a
Tonka type of furnace used in ... 1507
Treacher on tin in ... 738
Tringganu, tin in ... 659, 694, 699, 700, 960
Vercoe on tin near Malacca, at Kuala Lumpur, and Larut ... 740
On tin at Muntaha, Johore ... 741
Viator on tin at Gongong, Johore River ... 742
W———— on tin in ... 743
Wray on tin in ... 745, 746
On tin in Malacca and Tenasserim ... 744
On tin in Perak ... 747
Wildman on tin in Johore ... 308
See also Asia, Burmah, East Indies, Siam, Straits Settlements, and Sumatra.
Maleewoon, *see* Burmah, Maliwan.
Maliwan, *see* Burmah.
Mallada, L. ... 1037
Mallard, Ernest ... 522, 523
Mallet, F. R. ... 593, 594
Mallet, W. ... 605
Mallett, J. W. ... 1531
Mance, F. S. ... 52
Manche, *see* France.
Manès ... 552
Manganese, Allen on alloys of tin and ... 1431
Emmons on occurrence in United States and genesis of minerals of ... 1206
Fermor on the ores of in India ... 590a
Hennecke on occurrence in Persia ... 864
Manganese oxides, *see* Association of tin with.
Manganite, *see* Association of tin with.
Mangar district, *see* Billiton.
Mann, O. ... 553
Mantebras, *see* France, Montebras.
Manzano, Jesus P. ... 780

Reference Number

Marble Bar, *see* Western Australia.
Marche, *see* France, La Marche.
Margarite, *see* Association of tin with.
Marienberg, *see* Saxony.
Marinera mine, *see* Spain, Carthagene.
Marks, E. Seaborn..... 704a
Martaban, *see* India.
Martin, Joseph S..... 430
Martinamor, *see* Spain, Salamanca.
Masinde, *see* French Kongo.
Mason County, *see* Texas.
Massachusetts:
  Chesterfield, tin at the tourmaline locality at..... 750
  Day on tin in 1203a
  Goshen, tin from.....748, 749, 1214
  Hitchcock on tin from Goshen..... 748, 749
  Leonhard on tin at Goshen..... 1214
  Teschemacher on tin at Chesterfield..... 750
Massa Marittima, *see* Italy, Tuscany.
Massart, Alfred.....1038, 1343
Massinda, *see* French Kongo.
Massinga, *see* French Kongo.
Matam, *see* Borneo, Matan.
Matan, *see* Borneo.
Matther, W. W..... 1626
Maupas, *see* France, Morbihan.
Maures, *see* France.
Maynard, John..... 431
Mazade 524
Mazane, *see* Argentina.
McAuleys Lead, *see* New South Wales.
McCaskey, H. D..... 871
McCoy, Alexander..... 855
McCreath, A. S., and Platt, Franklin..... 1243
McKillop, John, and Ellis, Thos. F..... 1530
McKinlay River, *see* Northern Territory.
Mecklenburg County, *see* South Carolina.
Medicine, Boerhaave on medicinal use of tin..... 1305
Medlicott, H. B., and Blanford, W. T..... 595
Menado, *see* Celebes.
Mene, Ch..... 1532
Mengin, U..... 1533
Menniche, H..... 1534
Menten, J. H.....110, 297
Merawang district, *see* Banka.

Mercury: Reference Number
Campagne on mines of ... 1309
Capitaine on action of tin, arsenic, antimony, and sulphur on the chlorides of ... 1465
Douglas on metallurgy of ... 1204
Foniakoff on deposits in Siberia ... 965
Hennecke on occurrence in Persia ... 864
Poisoning produced by tin containing 1.3 per cent of ... 1436
Meredith, C. ... 1107
Merensky, H. ... 1184, 1185
Mergui district, *see* Burmah.
Mermet, A. (Delachanal, B., and) ... 1475
Merret, C. ... 432
Merrill, Geo. P. ... 1344
Mesa de los Caballos, *see* Mexico, Zacatecas.
Metallurgy of tin ... 1278, 1290
Argentina ... 38
Australia ... 1578
Ball on treatment of tin ores at Irvinebank, Queensland ... 891b
Betts on electrolytic lead refining ... 225
Boerhaave on ... 1305
British Columbia, Trail ... 231
California ... 222
China ... 266a
Clark on methods in Tasmania ... 1076
Collins on methods in Yunnan, China ... 266a
Cornwall ... 419, 422, 490, 1579
Dietzsch on treatment of tin-wolfram-copper ores ... 1479
Douglas on American improvements and inventions ... 1204
Douglas on ore crushing, concentration, and metallurgy of tin, etc. ... 1204
Fawns on ... 1320
Feuchtwanger on ... 1321
Kershaw on ... 1511a
Flower on history of ... 1390
Gmehling on in Bolivia ... 1497
Graham in ... 1324
Halse on ... 773
Hoskold on in Argentina ... 38
Japan ... 633
Kerl on methods in Cornwall ... 419
Leifchild on methods in Cornwall ... 422
Louis on ... 1523, 1524, 1526, 1527
Low on practices in Malay Peninsula and vicinity ... 704
Malay Peninsula ... 676c, 704, 706
McKillop and Ellis on at Pulo Brani, Singapore ... 1530
Menniche on recovering silver, lead, bismuth, tungsten, and copper from tin ores ... 1534

Metallurgy of tin—Continued. Reference Number
Morgan on methods in Malay Peninsula ... 706
Mulholland on the Greenbushes tin field, Western Australia ... 1265
Munroe on method at Taniyama, Japan ... 633
Nevius on ... 781
Ohly on ... 1215
Pearce on separation of copper, iron, etc., from tin ore ... 1547
Perret on ... 1549
Pike on ... 715
Pryce on ... 444
Queensland ... 891b
Reyer on ... 1354
Rowe on chemical methods of treating ores ... 1560
Schnabel, Handbook of metallurgy ... 794
Sexton on ... 1361
Simmons on methods in Black Hills ... 1019
Singapore ... 1530
South Dakota ... 1019
Tasmania ... 1076
Thibault on the metallurgy of complex tin sulphides ... 1577
On the metallurgy of tin in Australia ... 1578
Thiollier on methods in Cornwall ... 1579
United States ... 1215
Ure's dictionary on ... 1366
West on Temescal mines, California ... 222
Western Australia ... 1265
Wolf on the Betts process at Trail, British Columbia ... 231
Zirkel on methods in Cornwall ... 490
See also Assaying of tin, chemistry of tin, dressing of tin, milling of tin, refining of tin, and smelting of tin.
See references Nos. 1428–1587.
Metals, Haüy on metallic substances ... 1499
Metamorphism, Van Hise on ... 1367
Metasomatism in tin veins, Lindgren on ... 1337
Meteorites, Daubrée on tin in ... 1316
Tin in olivine found in ... 1600
Meunier, Stanislas ... 53, 705
Mexico:
Aguas Calientes, tin in ... 752, 759, 765
Aguilera on tin in ... 751, 752, 753
Allen on tin in Baja California ... 754
Baja California, tin in ... 754
Barcena on tin in Zacatecas and Lagos ... 761
Barriga on tin at Coneto in Durango ... 762
Beck on tin in ... 1299, 1300
Benedict on tin in ... 1301
On tin in Durango, etc ... 763

Mexico—Continued. Reference Number
Bergemann on analyses of tin from Xeres..... 1446
On tin in Xeres..... 764
Bretherton on tin in Jalisco and Aguas Calientes..... 765
Bromly on tin at Santa Barbara, Guanajuato..... 766
Chandler on tin in Durango..... 767
Collins on tin in Durango..... 768
Coneto, tin at.....755, 756, 762, 774
Del Mar on tin in..... 769
Durango, tin in....752, 755, 756, 762, 763, 767, 768, 770, 771, 773, 774, 776, 779, 783, 1635
Cacaria, tin at.....776, 777
Cerro de Iglesia de los Remedios, tin at..... 777
Mina del Diablo, hematite enclosing cassiterite at..... 1635
Potrillos, tin at.....776, 777
Sierra de Catalan, tin from..... 771
Fawns on tin in..... 1320
Fawns on tin in Durango and Sain Alto..... 770
Genth on tin from Sierra de Catalan, Durango..... 771
Grose on tin in..... 772
Guanajuato, tin in.....752, 766
Santa Barbara, tin at..... 766
Guerrero, tin in..... 757
Acamistla, tin at..... 757
Coapango, tin at..... 757
Taxco, tin in..... 757
Halse on tin in San Luis Potosi, Durango, Sain Alto, and Zacatecas.. 773
Halse on tin smelting at Las Cuevas..... 773
Hanks on tin near Coneto, Durango..... 774
Hidalgo, tin in..... 752
Humboldt on tin in..... 775
Ingalls on tin in Durango.....776, 777, 778
Jalisco, tin in.....752, 765
Kemp on tin in..... 1213
Kempton on tin in Durango and Zacatecas..... 779
La Esperanza, tin at..... 758
Lagos, tin in..... 761
La Minita, tin at..... 758
de Lapparent on tin in..... 1335
Las Cuevas, tin smelting at..... 773
La Santa Francisco, tin at..... 758
Lock on tin in..... 1338
Los Dos Amigos, tin at..... 758
Louis on tin in..... 1340
Manzano on tin in San Luis Potosi..... 780
Nevius on tin at Sain Alto..... 781

Mexico—Continued. Reference Number
Newland on tin in ... 1347
Newland on tin at Sain Alto ... 782
Pirsson on hematite enclosing cassiterite at Durango ... 1635
Pratt and Sterrett on tin in ... 252
Puebla, tin in ... 752
Querétaro, tin in ... 752
Richthofen on the age of the gold bearing deposits at Durango ... 783
Rolker on tin in ... 1357
Sain Alto, tin in ... 770, 773, 779, 781, 782
San Luis Potosi, tin in ... 752, 773, 780
Santa Maria del Rio, tin of ... 780
Sonora, tin in ... 752
Sterrett (Pratt and) on tin in ... 252
Tinnit, tin at ... 758
Wilson on tin and petroleum in ... 784
Xeres, analysis of tin from ... 1446
Tin in ... 764
Zacatecas, tin in ... 752, 761, 773, 779
Mesa de los Caballos, tin in ... 761
Meyers ... 1345
Meymac, *see* France.
Mica, Sadtler on deposits in the Black Hills, South Dakota ... 1016
See Association of tin with.
Michigan:
Keweenaw County, tin in ... 785
Stevens on tin in Keweenaw County ... 785
See also United States.
Mictis, Plinius on "white lead" on the island of ... 1408
Middlesex district, *see* Tasmania.
Midianites, tin among spoils of ... 1380
Miklucho, Maclay M. von ... 554
Miles, Edward T ... 705a
Millen, J. D ... 1107a, 1535
Miller, W. H ... 1627
Milling of tin:
Queensland ... 940a
South Dakota ... 987a
See Dressing of tin ore.
Mills-Davis, J. E ... 1185a
Milluni mine, *see* Bolivia.
Milne, J ... 789
Mina del Diablo, *see* Mexico, Durango.
Minchin, J. B ... 162, 163, 164, 165, 166, 167, 168, 169
Mineral Industry ... 1696

Reference Number

Mineralogy of tin....673, 674
Bauer on.... 1591
Blake on the ores of tin.... 1202
Cronstedt on.... 1599
Dana on.... 1600
Davey on.... 1603
Daubrée on.... 1314
Fawns on.... 1320
Feuchtwanger on.... 1321
France 516
Genth on 820
Haüy on.... 1615
Headden on.... 1208
Herman on.... 968
Jameson on.... 1621
Japan 632
Jermejev on crystals of tinstone from the Jenisei Region.... 1623
On crystals of tinstone from Transbaikalia.... 1622
Jimbo on cassiterite crystals from Japan.... 632
Lacroix on.... 516
Lacroix on cassiterite in France.... 516
de Launay on.... 1625
Leibius on the differentiation of the minerals of tin.... 1336
Liversidge on tin in New South Wales.... 828
Lock on.... 1338
Mather on artificial production of crystals of metallic tin.... 1626
Mulholland on the Greenbushes tin field, Western Australia.... 1265
New South Wales.... 828
Newland on.... 1347
Nicholls on crystals of cassiterite.... 1348
North Carolina....251, 252
Ohly on ores of tin in the United States.... 1215
Petterd on the minerals of Tasmania....1118, 1119, 1120, 1121
Phillips on.... 1633
Pratt on the Carolina tin belt.... 251
Pratt and Sterrett on the Carolina tin belt.... 252
Reyer on.... 1354
Rosenbusch on microscopic-optical properties of cassiterite.... 1639
Sexton on.... 1361
Siberia 1623
Simpson on properties and occurrence of cassiterite and stannite.... 1268
South Carolina....251, 252
Tasmania 1118, 1119, 1120, 1121
Tassin on cassiterite.... 1365
Transbaikalia 1622

Mineralogy of tin—Continued. Reference Number
United States ... 1215
Vlaanderen on ... 1647
Walker on identification of stream tin ... 1371
Western Australia ... 1265
See also crystallization of tin, occurrence of tin, origin of tin, and minerals of tin.
See references Nos. 1588–1649.
Minerals of tin ... 755
Clarke on ... 1311
D'Achiardi on ... 1313
Leibius on differentiation of ... 1336
Massart on ... 1343
Sexton on ... 1361
Ure's Dictionary on ... 1366
See Association of tin.
See the separate minerals of tin—ainalite, andrewsite, canfieldite, cassiterite, conradite, cuprocassiterite, cylindrite, franckeite, hulseite, native tin, nordenskiöldine, paigeite, plumbostannite, stannite, stokesite, teallite.
See also Slime tin, sparable tin, toad's-eye tin, and wood-tin.
Mingaye, John C. H. ... 831
Mining of tin:
Agricola on ... 1277
Argentina ... 38
Austria ... 67
Baldauf on methods in Cornwall ... 331
Balfour on methods in Malay Peninsula ... 677
Ball on Cornish methods ... 331b, 331c
Ball on methods in Cornwall compared with those in Queensland ... 331a
Ball on methods in Stanthorpe district, Queensland ... 889
Baudot on methods in Morbihan, France ... 498
Banka ... 74, 76, 77, 78, 84, 116, 117, 118
Banka, royalty paid to Government by tin mines ... 77
Becher on methods and machinery in Malay Peninsula ... 678
Billiton ... 117, 118, 134
Billiton, methods of working from commercial side ... 126a
Boers on power machinery for working tin ground in Banka ... 84
Bohemia ... 72
Bolivia ... 153a, 155a, 162, 167, 177
Bolivia, improvements in mining methods ... 148c
Bolivia, machinery used ... 148b
Brown on costs in Bolivia ... 153a
Burmah ... 204
Burmah, Mergui district ... 185
Cape Colony ... 234, 234a

Mining of tin—Continued. Reference Number
Carew on methods in Cornwall 351
Charleton on methods used in 1310
China 266a
Chinese method in Banka 76, 116
Clark on Tasmanian methods 1076
Cleland on methods at Stannary Hills, Queensland 897
Collett on methods in Malay Peninsula 681
Collins on Cornish mines and miners 368
On methods in Yunnan, China 266a
Conran on tin mining in Cornwall 370a
Cornwall 312, 329a, 329b, 331a, 331b, 331c, 351, 368, 370, 403, 413, 422, 433, 450a, 456, 1084, 1425, 1479
Methods illustrated by photographs 320
Working of low grade tin ores in 318
Davies on 1317
Devon 312, 403, 413, 1425
Dietzsch on reopening and working of Clitters mine, Cornwall 1479
Doyle on methods in Larut, Perak 688
East Indies, mining of tin and labor troubles in 675
Endter on methods in Bolivia 155a
Fawns on 1320
On methods at Mount Bischoff and at Dolcoath 1084
On methods and costs at Mount Bischoff, Tasmania 1083
Flower on history of 1390
Flower-Ellis on Chinese methods in Malay Peninsula 1489
On methods in Malay Peninsula 694a
France 498
Germany, Altenberg deposits 528
Gray on 1325
Great Britain 444
Griffiths on methods and costs in Cape Colony 234
Griffiths on mining in Cape Colony 234a
Hallwich on ancient and modern methods in Austria 67
Hampton on Chinese methods in Malay Peninsula 695
Henwood on methods used in 1327
Henwood on methods in Cornwall and Devon 403
Hoskold on in Argentina 38
Hunt on methods in Cornwall and Devon in 1868 413
Kayser and Provis on costs at Mount Bischoff, Tasmania 1102
Laos 642
Ledoux on methods and future of tin mining in North Carolina 248
Leifchild on methods in Cornwall 422
Lewis on costs at Anchor mine, Tasmania 1105
On removing overburden at Derby, Tasmania 1104
On tin mining in Tasmania 1106

Mining of tin—Continued. Reference Number
Lock on yield, methods used, and profits..... 1338
Louis on..... 1340
Maclaren on methods at Stannary Hills, Queensland..... 925
Malacca 299
Malay Peninsula....665, 676, 676b, 676c, 677, 678, 681, 694a, 695, 704a, 706, 713, 728, 730, 740, 1489
Chinese methods.....657, 658, 668, 678, 688, 695, 706, 715, 740
Labor troubles in..... 675
Marks on methods in Malay Peninsula..... 704a
Miller on new hydro-electric power plant at Mt. Bischoff, Tasmania..1107a
Mining terms explained.....1352, 1372
Moissenet on methods in Cornwall..... 433
Morgan on methods in Malay Peninsula..... 706
Mufford on methods in Tasmania..... 1115
Minchin on methods in Bolivia.....162, 167
Newbold on Malay and Chinese methods in Malacca..... 299
New South Wales.....834, 844, 844a
North Carolina..... 248
Parkes on methods in Malay Archipelago..... 713
Perak 688, 715, 738
Pike on Chinese methods in Perak..... 715
Pittman on mines and mining methods in New South Wales..... 834
Posewitz on methods in Billiton..... 134
Pryce on methods in Great Britain..... 444
Pryce on minerals, mines, mining, and mining terms and idioms.... 1352
Punnett on methods in Bolivia..... 177
Queensland.....331a, 889, 897, 925
Queensland, Stanthorpe, dredging plant at..... 883
Reyer on nature and condition of mining in Banka and Billiton.... 117
Richter on..... 1356
Rickard on improvements in methods in Cornwall..... 450a
Rolker on costs, labor, and tools in Siak district, Sumatra..... 305
Sexton on..... 1361
Siam, dredging operations in Tongkah Harbor..... 676
Simmons on tin mining in the Black Hills, South Dakota..... 1019
Skewes on, in Cornwall..... 456
Smyth on..... 1362
South Dakota..... 1019
Sowden on works at Mount Bischoff, Tasmania..... 1131
Stephens on tin mining at Pahang, Malay Peninsula..... 728
Stokes on methods in Malay Peninsula..... 730
Stokes on new electric plant at Mount Bischoff, Tasmania..... 1133
Sumatra 305
Tasmania....1076, 1083, 1084, 1102, 1104, 1105, 1106, 1107a, 1115, 1131, 1133
Methods of working, expenses, and profits.....1064, 1069, 1070

Mining of tin—Continued. Reference Number
Thibault on dredging methods and results in New South Wales..... 844
Treacher on labor, wages, contracts, and mining methods in Perak, 738
Tremenheere on methods in Mergui district, Burmah..... 204
Trenchard on sluicing plants at Tingha, New South Wales.....844a
Van der Wyck on methods in Banka and Billiton..... 118
Vercoe on Chinese methods in Malay Peninsula..... 740
Vogelsang on methods in Schlaggenwald, Bohemia..... 72
Weeks on methods, machinery, and technical terms..... 1372
Worth on tools and methods in Devon and Cornwall (historical)... 1425
See references Nos. 1650–1658.
Mining laws:
Bartlett on British mining laws..... 334
Boase and Courtney on British mining laws..... 342
Carew on court practices in Cornwall..... 351
China, Yunnan..... 266a
Legislation regarding tin in Malay Peninsula.....681, 706
Mining terms explained..... 444
Glossary of..... 483
Pryce on..... 1352
Weeks on..... 1372
Mino, *see* Japan.
Misina, Graham on tin in.....1324
Mispickel, Whitehead on assays of, from Virginia..... 1247
See Association of tin with.
Missouri, Dunstan on tin in..... 786
Genth on tin in Madison County..... 787
Madison County, tin in..... 787
Ozarks, tin mining fraud in..... 1423
Wheeler on attempted tin mining in..... 1423
See also United States.
Missouri River, *see* Montana.
Mitta Mitta, *see* Victoria.
Mitta River Valley, *see* Victoria.
Mohlengraaff, G. A. F..... 1052
Moho district, *see* Peru, Puno.
Moissenet, L..... 1536
Moissenet, Leon.....433, 434
Moissenet, L. L..... 435
Molong district, *see* New South Wales.
Molybdenite, Andrews on deposits at Kingsgate, New South Wales..... 797
See Association of tin with.
Molybdenum, Clarke on separating tin from arsenic, antimony, and molybdenum 1467
Monaglogh, *see* Ireland.

Reference Number

Monazite, distortion of cassiterite crystals caused by 1649
Voit on deposits of in South Africa 3c
See Association of tin with.
Montalbion, *see* Queensland.
Montana, Bitter Root Mountains, tin in 214
Blake on tin in 1202
Blake on tin in the headwaters of the Missouri 1201
Blake on tin in the Bitter Root Mountains 214
Kemp on tin in 1213
Missouri River, tin in headwaters of 1201
Raymond on stream tin on Big Prickly Pear Creek 787a
See also United States.
Monte Blanco mine, *see* Bolivia.
Montebras, *see* France.
Montebrasite, *see* Association of tin with.
Monte Calvi, *see* Italy, Tuscany.
Monte Fumachhio, *see* Italy, Tuscany.
Montesinhos, *see* Portugal.
Monte Valerio, *see* Italy, Tuscany.
Montgomery, Alex 1108-1113
de Montis, E. 586a
Moody, S. E. 1537
Moore, T. 1114
Moorina, *see* Tasmania.
Morbihan, *see* France.
Morgan, J. 706
Möricke, W. 260
Morococala mine, *see* Bolivia.
Morse, Arthur J. 1013
Moss, E. W. 707
Mount Amos, *see* Queensland.
Bischoff, *see* Tasmania.
Black, *see* Tasmania.
Brown, *see* Queensland.
Calvario, *see* Peru.
Cameron, *see* Tasmania.
Cudgewa, *see* Victoria, Cudgewa district.
Dundas, *see* Tasmania.
Elmo, *see* Victoria.
Euriowie, *see* New South Wales.
Fatique, *see* Victoria.
Gunson mine, *see* South Australia.
Leswell, *see* Queensland.
Lyell, *see* Tasmania.
Mica, *see* Maine.
Pilot, *see* New South Wales.

Reference Number

Mount Amos—Continued.
Poscovi, *see* Bolivia.
Ramsay, *see* Tasmania.
Read, *see* Tasmania.
Rex, *see* Tasmania, Ben Lomond.
Rubellite, *see* Maine.
Singapore, *see* Victoria.
Wells, *see* Northern Territory.
Wills Creek, *see* Victoria.
Mourne Mountains, *see* Ireland.
Mufford, J. 1115, 1116
Mulder(?) 1538
Muldiva, *see* Queensland.
Mulholland, C. A. 1265
Muller, H., and Richter 560
Müller, Hermann 555, 556, 557, 558, 559
Muller, J. A. 1539
Munday, John 927
Munroe, Henry S. 633
Muntaha, *see* Malay Peninsula, Johore.
Muntok district, *see* Banka.
Murray, Reginald A. F. 1230, 1231
Murray (Upper), *see* Victoria, Upper Murray.
Muriate of tin, Gregor on formation through long burying of metallic tin, 393
Hunt on influence of magnetism and voltaic electricity on crystallization of 1619
Muscovite, *see* Association of tin with.
Musculus, F. 1540
Myola, *see* Queensland.
Myrick, C. M. 1541

N

Nails, made from tin scrap 1573
Nam-Patene, *see* Siam, Laos.
Nam Sak River, *see* Siam.
Nancothan, *see* Cornwall.
Napier, Chas. R. G. 1405
Narungo, *see* India, Chota Nagpur.
Native tin, ... 347, 527, 856, 860
Nederlandsch Indie, *see* Dutch Indies.
Neeb, E. A. 298
Negri Sembilan, *see* Malay Peninsula.
Negro Pabellon, *see* Bolivia.
Nellys Ford, *see* Virginia, Nelson County.
Nelson County, *see* Virginia.
Neudeck, *see* Bohemia.

Reference Number

Nevada, Hoffman on tin in Tuscarora placer mines..... 788
See also United States.
Neville, F. H. (Heycock, C. T., and)..... 1504
Nevius, J. Nelson..... 781
Newbery, J. Cosmo..... 1232
Newbold, T. J..... 299
Newellton district, *see* Queensland.
New England plateau, *see* New South Wales.
New England States, Blake on tin in..... 1202
See also Australia.
Newfoundland, Milne on tin in..... 789
New Guinea, Ferguson Island, tin on..... 790
New Hampshire, Day on tin in..... 1203a
Jackson, tin at.....791, 792, 1214
Kemp on tin in..... 1213
Leonhard on tin at Jackson..... 1214
See also United States.
New Jersey, Andover, tin near..... 793
Lesley on tin near Andover..... 793
Schnabel on tin in zinc from..... 794
See also United States.
Newland, D. H.....30, 31, 54, 70, 170, 436, 437, 708, 782, 832, 833, 928, 1053, 1266, 1346, 1347
Newman 1117
Newman, G. H..... 929
Newquay, *see* Cornwall.
New Ross, *see* Nova Scotia, Lunenberg County.
Newsom, John F. (Branner, J. C., and)..... 1306
New South Wales, tin in.....41, 43, 45, 46, 1290, 1292, 1298c
A————, R. D., on tin mining in Vegetable Creek district..... 796
Aberfoil River, tin on..... 820
Adams on tin in..... 795
Andrews on tin in the New England plateau..... 797
Badjerican mine, tin in..... 825
Bald Nob, tin at..... 797
Barrier Bischoff mine, tin in..... 825
Barrier Ranges field, tin in..... 825
Beer on tin in..... 806
Bendemeer, Gulf mine, tin in..... 817
Benedict on tin deposits of.....47, 1301
Benedict on Oetery mine in Emmaville district..... 807
Bourke County, tin in..... 841
Brögger (Kjerulf and) on tin in..... 826
Broken Head, beach mining at..... 805

New South Wales—Continued.	Reference Number
Broken Hill Lode, tin in	825
Brown on tin in	1307, 1308
Burra Burra district, tin in	847a
Caloria mine, tin in	825
Card on minerals of economic value in	808
Carne on beach sand of the Esk River and Jerusalem Creek, Richmond County	809
Clarence district, tin in	822, 823
Clarke on tin in	810, 811, 812, 813
Clark on tin mines in the Devonian of	814
Coglan on tin in	815, 1677, 1679
Conder on the Conrad tin mines	816
Cotton on the tin deposits of New England	816a
Cox on tin near Bendemeer, in Inverell district, and at Silverton	817
David on the Vegetable Creek field, New England district	818
Davies on tin in	1317
Day on tin in	1318
Deepwater, tin at	797
Department of mines on tin in	819
Dundee, tin near	811
Emmaville district	797, 800, 807
Emmaville district, Emerald mines, tin in	797
English on tin in the Inverell district	50
Euriowie, tin at	825
Evans on Little River to McAuley's Lead, beach mining from	804
Fawns on tin in	1320
Foullon on tin in	1322
Genth on tin from Aberfoil and Sam Rivers	820
Giants Den, tin at	797
Gower on the Vegetable Creek field	821, 822, 823, 824
Howell, Conrad mines, conradite from	1644
Conrad mines, tin in	816
Huel Byjerkerno mine, tin in	825
Inverell district, tin in	50, 797, 803, 817, 844, 847c
Elsmore mine, tin in	830, 849
Jaquet on tin in Euriowie and Waukeroo	825
Kjerulf and Brögger on tin in	826
Liversidge on tin in	827, 828, 829
Liversidge on Elsmore mine, Inverell	830
Lock on tin in	1338
Louis on tin in	1340
Louis (Phillips and) on tin in	1350
Mance on tin mining in 1905	52
McAuleys Lead to Evans or Little River, beach mining from	804
Mingaye on tin in the Richmond River district	831

New South Wales—Continued. Reference Number
Molong district, Gumbel lodes, tin in ... 847g
Mount Euriowie, tin in ... 825?, 848
Mount Pilot, tin at foot of ... 41, 799
New England district, tin in ... 797, 816a, 818, 822, 840, 842, 845
Newland on tin in ... 832, 833, 1346
Newton on metalliferous minerals of ... 55
Paradise Creek, tin in ... 811
Pheasant Creek, tin at ... 797
Phillips and Louis on tin in ... 1350
Pittman on tin in ... 834, 835
Plummer on tin in ... 837
On tin in Vegetable Creek field ... 836
Reid on tin in ... 838
Reyer on tin in ... 1354
Richmond County, Jerusalem Creek, beach sand of ... 809
Esk River, beach sand of ... 809
Richmond River, beach mining at mouth of ... 804, 831
Sam River, tin on ... 820
Silverton, tin at ... 817
Silverton district, Poolamacca, tin near ... 847h
Silent Grove, tin at ... 797
Slee on tin in ... 839
Smyth on tin in ... 1362
Stephen on tin in New England district ... 840
Stokes on tin in ... 730
Stonier on tin in Bourke County ... 841
Taylor on tin in the New England district ... 842
Thibault on tin in ... 843
On conradite from the Conrad mines, at Howell ... 1644
On tin dredging in Tingha ... 844
Thistle mine, tin in ... 825
Timbarra, Table Top, gold at ... 797
Tingha, stream sluicing plants at ... 844a
Tin dredging at ... 803, 844
Tingha district, map showing tin in ... 849
Trenchard on stream sluicing plants at Tingha ... 844a
Ulrich on tin in New England district ... 845
Vegetable Creek district, tin in ... 796, 818, 821, 822, 823, 824, 835, 836, 847f
Waukeroo, tin in ... 825
Weinschenk on tin in Silberberg near Bodenmais ... 846
Wilkinson on tin in ... 847b, 847d, 847e
On tin in the Burra Burra district ... 847a
On tin in the Inverell district ... 847c
On tin in the Molong district ... 847g

	Reference Number
New South Wales: Wilkinson—Continued.	
On the Mount Euriowie tin properties	848
On tin in the Silverton district	847h
On tin in the Tingha and Elsmore districts	849
On tin in the Vegetable Creek district	847f
Wilson's Downfall, tin at	797
Wood on tin in	850
See also Australia.	
Newton, E. Wilton	55
New Zealand:	
Bell on tin on Stewart Island	852
Binns on tin on west coast of Otago and South Island	853
Coghlan on tin in	1077
Fawns on tin in	1320
Half Moon Bay, tin at	851
de Launay on tin in	854
McKay on tin in the Port Pegasus district and on Stewart Island	855
Newton on metalliferous minerals of	55
Otago, tin at Laukeys Creek, Reefton, Milford, and Dusky Sounds on west coast of	853
Port Pegasus district, tin in	855
Remarkable Mountains, tin in	853
South Island, tin at Humphreys Gulley near Hokitika	853
Stewart Island, tin on	851, 852, 853, 855
Neyrac, *see* France.	
Nicholas, C. E.	929a
Nicholas, Wm.	1233
Nicholls, Dr.	1348
Nickel, Emmons on occurrence in United States and genesis of minerals of	1206
Douglas on metallurgy of	1204
Moody on hydrolysis of salts of, in presence of iodides and iodates	1537
Perret on metallurgy of	1549
World statistics since 1890	1694
See Association of tin with.	
Nicolaus, R. C.	860
Nigeria, tin in	637, 638
Akwa-Ibama district, tin in	859
Bauchi, tin in Badiko district	860
Bautshi tin fields	857
Benue River, tin on the	3
de Launay on tin on the Benue River	3
Delime River, tributary to Lake Tchad, tin on	856
Dunstan on the Bautshi tin fields	857
On tin from the Tilde area and the River Gimpu	858
On tin in the Uwet and Akwa-Ibama districts	859

Nigeria—Continued. Reference Number
Fawns on tin in ... 1320
Gimpu River, tin on ... 858
Gimpy or Kogin-Delume River, tin on the ... 860
Kogin-Delume River, *see* Gimpy River.
Nicolaus on tin in the Badiko district, Bauchi, and on the Gimpy or Kogin-Delume River ... 860
Stokes on tin in ... 730
Tilde area, tin in ... 858
Uwet district, tin in ... 859
See also Africa.
Nigger Hill district, *see* South Dakota.
Nine Mile Creek, *see* Victoria, Mitta River Valley.
Niobium, de Launay on occurrence in France ... 518
See Association of tin with.
Niriella, *see* Ceylon.
Nöggerath, J. J. ... 1628
Noragala, *see* Ceylon.
Nordenskiöld, A. E. ... 948, 1628a
Nordenskiöldine, Brögger on a rare borate of calcium and tin ... 1596
Dan on ... 1600
North, Oliver ... 1542
North America, *see* Alaska, Canada, Greenland, Mexico, Newfoundland, Santo Domingo, United States, etc.
North Carolina, tin in ... 1196, 1281, 1298
Benedict on tin in ... 240, 1200, 1301
Dabney on Kings Mountain tin deposit ... 241
Day on tin in ... 1203a
Emmens on tin in ... 1205
Furman on tin in ... 242, 242a
Garrison on tin in ... 243, 1207
Genth on tin at Kings Mountain and on other minerals in ... 244
Graton on tin in ... 245, 246
Guenther on tin in ... 1326
Headden on tin in Mecklenburg County ... 1208
Hess on tin in ... 247
Kalb on cassiterite in Haywood and Henderson counties ... 1334
Kemp on tin in ... 1213
Kings Mountain tin deposit ... 240, 241, 242a, 244, 247, 248, 254, 254a
Ledoux on tin at Kings Mountain ... 248
Mecklenburg County, analysis of cassiterite supposed to be from ... 1208
Phillips on tin in ... 250
Pratt on tin in ... 251
Pratt and Sterrett on tin in ... 252
Rolker on tin in ... 1357
Struthers and Pratt on tin in ... 1364

	Reference Number
North Carolina—Continued.	
Ulke on tin at Kings Mountain	254
Van Ness on tin at Kings Mountain	254a
See also Carolinas and United States.	
North Dundas, *see* Tasmania.	
Northeastern district, *see* Victoria.	
Northern Hills, *see* South Dakota, Black Hills.	
Northern Territory, tin in	45, 1292, 1298c
Fawns on tin in	1320
Playford on tin at Warra	861a
Port Darwin, tin at	861
Tate on tin near Mt. Wells and on a tributary of McKinlay River	862
Warra, tin at	861a
Wood on tin in	863
See also Australia.	
Norton Bay, *see* Alaska.	
Norway, Brögger on the minerals of the syenite pegmatite	1596
Brögger on tin in Arö	1596
See also Europe.	
Nova Scotia, Fairibault on tin in Lunenberg County	227
Lunenberg County, tin at New Ross	224, 227, 232
Lunenberg County, tin at Tangier, Shelbourne, Rawdon, Country Harbour, and New Ross	227
Young on geology of country near New Ross	232
See also Canada.	
Nowicki, Constantin von	71
Noyes, H. Herbert	709
Nurgo, *see* India, Chota Nagpur.	
Nurunga, *see* Narungo.	
Nylstroom, *see* Transvaal.	

O

Oates, Robert	596
Occurrence of tin	1280, 1288, 1293, 1294
Alaska	8, 12c, 17, 21, 29a, 29b, 31
Andrews on the tin deposits of New England, New South Wales	797
Argall on wood tin in Breage, Cornwall	330
Argentina	36
Argentina, Tinogasta, in granulite	36
Balfour on tin in Malay Peninsula	677
Banka	118, 136
Bauer on	1591
Beck on	1299
Beck on the mineral deposits of Schwartzenberg	530
Benedict on tin and bismuth in closely associated but distinct veins at Chorolque, Bolivia	152

Occurrence of tin—Continued. Reference Number
Bergeat on the tin deposits of Tuscany 613
Berger on matrices accompanying mineral deposits of Cornwall and Devon 339
Berzélius on 1302
Billiton 118, 134, 136
Blake on tin ore in the Black Hills, South Dakota 994
Boerhaave on 1305
Bohemia 542, 573a
Bolivia 141a, 143, 144, 152, 154, 155, 157, 158, 172
Branner and Newsom on 1306
Brooks on occurrence of cassiterite in Alaska 17
Brown on 1307
Burmah 196, 202
Busz on cassiterite in hornfels in Devon 350
Buttgenbach on cassiterite-bearing lodes in Katanga 275
California 214, 215, 222, 223
Campagne on the mines of tin 1309
Canada, Ottawa Valley 230
Cape Colony 3b, 234
Card on occurrence of tin ore 808
Carne on chlorite schist pebbles cemented by crystallized tin in Relistian mine, Cornwall 352
Carolinas, pegmatite dikes with cassiterite as original constituent .. 239
Carpenter on tin in the Black Hills, South Dakota 998, 999
China 266a, 269a
Collier on tin in granite dike intersecting limestone in Alaska 21, 31
Collins on tin in west of England 367
On tin in Yunnan, China 266a
Comstock on tin in Texas 1166
Conder on the Stanley River tin field, Tasmania 1078a
Conway on tin veins in porphyry, slate, and trachyte in Bolivia 154
Cornwall 330, 339, 352, 384, 427, 433, 442, 455
Cotta on 1312
Cotton on the tin deposits of New England, New South Wales 816a
Cox on lode and alluvial deposits in New South Wales 817
Dalmer on the tin deposits of the Altenberg-Graupen district of Germany 542
Daubrée on 1314, 1315, 1316
David on tin deposits of the Vegetable Creek field, New South Wales, 818
Davies on 1317
De La Croix on tin in Perak 685
Devon 339, 350
Dinsmore on tin in Franklin Mountains, Texas 1168a
Dunstan on tin deposits of Stannary Hills, Queensland 904
Dussauce on 1482

Occurrence of tin—Continued. Reference Number
Emmons on occurrence in the United States..... 1206
Emmons on tin ore in andesitic or trachytic rocks of Cretaceous or Tertiary age in Bolivia..... 155
England 367, 452
English on tin in decayed granite, porphyry, and quartzose rock at Mt. Bischoff, Tasmania..... 50
Fairbanks on system of tin veins in Temescal district, California, 215, 216
Fawns on..... 1320
Feuchtwanger on..... 1321
Finland 953a
Forbes on occurrence of tin ore in Bolivia..... 157
Foster on tin ore as lenticular layers between bedding planes of killas in Cornwall..... 384
France 522
France, Montebras, at contact of granite and feldspathic porphyry, 494, 517
Frochot on the grading of SnO_2 into tin pyrites at depth in Bolivia, 158
Germany 530, 542, 573a
Germany, Altenberg deposits..... 528
Grading of SnO_2 into tin pyrites at depth in Bolivia..... 143
Graton on cassiterite as a primary constituent of pegmatite dikes in Carolina tin belt.....245, 246
Greg and Lettsom on..... 1614
Griffiths on tin in porphyritic granite in Cape Colony..... 234
Hanks on..... 218
Hess on cassiterite as an original mineral in pegmatite..... 247
Hess and Graton on..... 1329
Italy 613, 627
Jameson on..... 1621
Johnston on Tasmanian tin deposits..... 1099
Jokèly on tin in gneiss, felsite, porphyry, and greisen..... 68
Kalb on..... 1334
Kitson on deposits in Victoria..... 1229
Knopf on tin minerals in Alaska.....29a, 29b
Kongo 3, 275
Krusch on tin deposits of Western Australia..... 1258
Lacroix on cassiterite at Hin-boun, Laos..... 644
Laos 644
de Launay on cassiterite in pegmatite cutting mica, talc, chlorite, and amphibolite schists at Embabaan, Swaziland..... 3
de Launay on tin with copper in region of Archæan rocks and granite in the French Kongo..... 3
Lemon and Tremenheere on cassiterite in granite dikes cutting sandstone in Mergui, Burmah..... 196
Lock on rocks in which tin occurs..... 1338
Lotti on the tin deposits of Tuscany..... 627

Occurrence of tin—Continued. Reference Number
Louis on 1340
MacAlister on tin lodes of Cornwall 427
Malay Peninsula 677, 714
Mallard on tin veins in granite carrying black mica in Montebras, France 522
Massart on tin ores in Spain 1038
Minchin on tin veins in trachytic porphyry 162, 164
Moissenet on tin veins of Cornwall 432
Montgomery on Tasmanian tin deposits 1110, 1112
Munday on tin ores of Herberton district, Queensland 927
Newland on tin in granite dike intersecting limestone near Lost River, Alaska 2b
New South Wales 797, 816a, 817, 818
Nicholls on 1348
North Carolina 239, 245, 246, 247, 1220
Occurrence, appearance, and detection of tin in the field 1298e
O'Harra on minerals of the Black Hills, South Dakota 1014
Ohly on tin in the United States 1215
Osann on cassiterite in graphitic gneiss derived from limestone in the Ottawa Valley, Canada 230
Pacheco on tin ores in Spain 1039
Pasley on tin veins in granite and later "porphyritic rocks"—trachytic in the south—of Bolivia 172
Penrose on tin deposits of Malay Peninsula 714
Perak 685
Phillips on the rocks of Cornwall in which mineral deposits occur 442
Pilz on 1040
Posewitz on occurrence in Billiton 134
Preumont on tin bearing lodes in quartzite 176
Puig y Larraz on tin in Zamora, Spain 1041
Queensland 904, 927
Recknagel on the tin deposits in the Rooiberg district, Transvaal, 1186a, 1186b
Reilly on 1353
Rudler on occurrence of cassiterite and stannite in Great Britain 452
Rumbold on tin deposits of Cape Colony, Transvaal, and Swaziland 3b
Sandberger on occurrence in silicates 1358
Saxony 542, 573a
Sexton on 1361
Simmons on tin ores in Cornwall 455
Singewald on tin deposits in the Erzgebirge of Saxony and Bohemia. 573a
Smyth on 1362
South Carolina 239, 245, 246, 247, 1220
South Dakota 994, 997, 998, 999, 1009, 1014, 1020, 1221
Spain 1038, 1039, 1041

Occurrence of tin—Continued. Reference Number
Stelzner on tin grading into argentiferous fahlerz, pyrites, and locally galena and zinc blende at depth in Bolivia..... 182
Stelzner on tin ore in trachytes or andesites of Cretaceous or early Tertiary age in Bolivia..... 182
Stirling on tin deposits of Victoria..... 1238
Struthers and Pratt on tin in North and South Carolina..... 1220
Struthers and Pratt on tin in South Dakota and Wyoming..... 1020
Swaziland 3, 3b, 3d
Swinburne on tin in the Transvaal..... 1189
Tasmania.....50, 1078a, 1099, 1110, 1113, 1155, 1156, 1158
Texas 1166, 1168a
Theobald on tinstone as one of the integral constituents of a stanniferous granite south of Pakchan, Burmah..... 202
Transvaal.....3d, 1178d, 1186a, 1186b, 1189
Trustedt on iron, copper, and tin deposits at Pitkäranta, Finland... 953a
Tuscany 613, 627
Ulke on deposits at Kings Mountain, North Carolina, and Vesuvius, Virginia 254
United States.....1206, 1215
Van der Wyck on occurrence in Banka and Billiton..... 118
Verbeek on occurrence of tin in Banka and Billiton..... 136
Victoria 1229, 1238
Virginia 254
Waller on tin in Tasmania.....1155, 1156, 1158
Warth on cassiterite in weathered eruptive rock..... 207
Weeks on..... 1372
West on Temescal mines, California..... 222
Western Australia..... 1258
Weston on tin deposits of Swaziland and Transvaal..... 3d
Whitney on Temescal mines, California..... 223
Willis on tin in Yunnan, China..... 269a
Wyoming 1020
Ochsenius, C..... 171
Oetery mine, *see* New South Wales, Emmaville district.
O'Harra, Cleophus C..... 1014
Ohira-tetsu-san, *see* Japan, Bungo.
Ohly, J..... 1215
Olaechea, T..... 171a
Oldham, T.....198, 199
Olivine, tin in olivine found in meteorite..... 1600
Onon River, *see* Siberia.
Oonah mine, *see* Tasmania.
Oppe, H. V..... 561
Oppert, Ernest 640
Orange River Colony, Jorissen on intrusive granites in.....1050

Reference Number

Ordway, John M. 1543
Orense, *see* Spain.
Orient farm, *see* Tasmania.
Origin of tin 1298a
Alaska 19
Andrews on the tin and wolfram deposits of New England, New South Wales 797
Australia 58
Beck on 1299
Beck on the mineral deposits of Schwartzenberg 530
Beck on relation between ore veins and pegmatites 1300
Bergeat on the tin deposits of Tuscany 613
Berthelot on 1379
Blake on tin ores of the Black Hills, South Dakota 995
Blake on the ores of tin 1202
Bohemia 542
Bolivia 158, 160, 180a, 182
Branner and Newsom on 1306
Breithaupt on the paragenesis of minerals 535
Carne on the source of the tin in beach sands of New South Wales .. 809
Carne on stream tin in Cornwall 356
Collier on stream tin in Alaska 19
Collins on, in the west of England 367
Cornwall 356, 385, 399, 402, 404, 410, 427
Cotta on 1312
Cotta on gradual passage from granite to stanniferous zwittergestein in Germany 539
Cotton on the tin deposits of New England, New South Wales 816a
Dalmer on the tin deposits of the Altenberg-Graupen district, Germany 542
Daubrée on 1314, 1315, 1316
David on the tin deposits of the Vegetable Creek field, New South Wales 818
Emmons on 1206
England 367, 452
Fawns on 1320
Finland 953a
Foster on tin deposits of Cornwall 385
Frochot on tin deposits of Bolivia 158
Gautier on tin deposits near Chorolque, Bolivia 160
Germany 530, 539, 542, 575
Graton on tin deposits of the Carolina tin belt 245, 246
Hall on tin deposits of Pretoria 1181, 1182
Hawkins on origin of alluvial strata in Cornwall 399
Headden on tin in the Black Hills, South Dakota 1008

Origin of tin—Continued. Reference Number
Henwood on derivation of stream tin..... 1327
On the stream tin deposits of Cornwall.....402, 404
Hess on the Carolina tin deposits..... 247
On tin in South Dakota..... 1009
Hill on tin deposits of Cornwall..... 410
Hopkins on alluvial tin deposits..... 1330
Hunt on Mt. Bischoff tin deposits..... 1097
Italy 613, 627
Jackson on the tin bearing veins of Jackson, New Hampshire, 791, 792
Johnson on tin deposits in South Africa..... 1183
Krusch on tin deposits of Western Australia..... 1258
Lacroix on cassiterite at Hin-boun, Laos..... 644
Laos 644
Lindgren on metasomatic processes in fissure veins..... 1337
Lotti on the tin deposits of Tuscany..... 627
MacAlister on tin and tourmaline..... 1341
On tin lodes of Cornwall 427
Majendie on wood tin..... 1342
Malay Peninsula.....714, 721, 725, 726b
Merensky on tin deposits of Transvaal.....1184a
New Hampshire.....791, 792
New South Wales.....797, 809, 816a, 818
North Carolina.....245, 246, 247
Penrose on alluvial and lode tin in Malay Peninsula..... 714
Pošepný on the genesis of ore deposits..... 1351
Pretoria.....1181, 1182
Recknagel on the tin deposits of the Rooiberg district, Transvaal, 1186a, 1186b
Recknagel on the tin deposits of South Africa..... 3a
Reyer on..... 1355
Richter on the relations between tin, lead, and zinc..... 1356
Robertson on stream tin in Australia..... 58
Rudler on tin deposits of Great Britain..... 452
Rumbold on origin of Bolivian tin deposits..... 180a
On tin deposits of Malay Peninsula..... 721
Saxony.....530, 542, 575
Scrivenor on tin deposits of Malay Peninsula.....725, 726b
Sedgwick on..... 1360
South Africa.....3a, 1183
South Carolina.....245, 246, 247
South Dakota.....995, 1008, 1009, 1024
Stelzner on tin deposits of Bolivia..... 182
Stelzner on tin deposits of the Erzgebirge of Germany..... 575
Stevens on..... 1363
Stirling on tin deposits of Victoria..... 1238

Origin of tin—Continued. Reference Number
Tasmania....1097, 1137, 1141, 1155, 1156, 1158, 1159
Texas 1172
Transvaal....1181, 1182, 1184a, 1186a, 1186b
Trüstedt on the iron, copper, and tin deposits at Pitkäranta, Finland, 953a
Tuscany 613, 627
Twelvetrees on tin mines of Tasmania....1137, 1141
Ulke on tin ores of South Dakota.... 1024
United States.... 1206
Van Hise on.... 1367
Victoria 1238
Vogt on....1368, 1369, 1370
Waller on tin in Tasmania....1155, 1156, 1158
Weed on tin deposits at El Paso, Texas.... 1172
Wellington on Mt. Bischoff mine, Tasmania.... 1159
Western Australia.... 1258
See also Association of tin and Minerals of tin.
Orthoclase, Phillips on pseudomorphs of cassiterite after.... 1632
See Association of tin with.
Ormuz mine, *see* Tasmania.
Oruro, *see* Bolivia.
Osann, A.... 230
Osbeck, Peter.... 710
Oshoek, *see* Swaziland.
Otago, *see* New Zealand.
Oubanghi, *see* French Kongo, Ubangi.
Oudemans, Jr., A. C.... 111
Ouelle Makua, *see* French Kongo, Welle Makwa.
Overman, Frederick.... 1544
Ovoca district, *see* Ireland, Wicklow.
Owen, Frank....711, 712
Oxland, R.... 438

P

Pacheco, Hernandez E.... 1039
Pahang, *see* Malay Peninsula.
Paigeite, Knopf on a new magnesian iron-tin boron mineral....29a, 29b
Paillette, Adrien (Schulz, Guillaume, and).... 1043
Pakchan River, *see* Burmah, Tenasserim district.
Pak-Phrëk, *see* Siam.
Palanpur, *see* India.
Palmer district, *see* Queensland.
Palmer River, *see* Queensland.
Palo, *see* East Indies.
Palembang, *see* Sumatra.
Panga, *see* Siam.

Reference Number

Pangkal-Pinang district, *see* Banka.
Pansner, Hofrath 269
Papkuilsfontein, *see* Cape Colony.
Pappan, *see* Malay Peninsula, Perak.
Papua, *see* New Guinea.
Paradise Creek, *see* New South Wales.
Parcelore, *see* Malay Peninsula.
Paris, John Ayrton 439
Parkes, Chas. R. 713
Park of Mines, *see* Cornwall.
Parry, L. 1545, 1545a, 1545b
Parsons, James 259
Parsons, James (Coomaraswamy, A. K., and) 257
Pascoe River, *see* Queensland.
Pasley, Charles S. 172
Pattison, S. R. 1406
Pavlov, A. W. 32, 1216
Payne Mill, *see* British Columbia, Slocan district.
Pearce, Gilbert B. 1407
Pearce, Richard 440, 441, 1447a, 1546, 1547, 1629, 1630, 1660
Peetz, L. 1548
Pegu, *see* Malay Peninsula.
Pelatan, L. 645, 648
Pemberthy, John 174
Peña, Alphonso de la 172a
Penberthy, John 173, 467
Penfield, S. L. 1631
Pennance mine, *see* Cornwall.
Pennington County, *see* South Dakota, Black Hills.
Penrose, R. A., Jr. 714
Pentowan mine, *see* Cornwall.
Pentuan, *see* Cornwall.
Penzance, *see* Cornwall.
Perak, *see* Malay Peninsula.
Perlis, *see* Siam.
Permo-carboniferous, Twelvetrees on tin in, in Tasmania 1137
Perrett, Auguste 1549
Persia, Hennecke on tin in 864
  Mactear on tin near Juwaa, 60 miles northeast of Tabriz 865
  See also Asia.
Personne, J. 1550
Peru:
  Cajatambo, west of Cerro de Pasco, tin at 866
  Earl of Mount Edgcumbe on tin produced in 1883 1681

Peru—Continued. Reference Number
Kersten on tin in 1512
Larrouy on tin near Huancane, Puno 867
Mount Calvario, tin on 180
Olaechea on tin in Puno 171a
Posth on tin in the Vilque district, Puno 869
Puno, tin in 171a, 866, 867, 869, 870
Huancane, tin near 866, 867, 870
Moho district, tin in 866, 870
Vilque district, tin in 866, 869
Raimondi on tin in the Moho district, Puno 870
Romaña on tin on Mount Calvario in Vilque Chico 180
Vilque Chico, tin in 180
See also South America.
Petterd, W. F. 1118-1121
(Twelvetrees, W. H., and) 1149
Pheasant Creek, *see* New South Wales.
Philippine Islands, McCaskey on reported tin in Negros 871
See United States.
Phillips, J. A., and Louis, H. 628, 1350
Phillips, J. Arthur 442, 1349, 1632
Phillips, John 1661
Phillips, Wm. 443, 1633, 1634
Phillips, Wm. B. 6, 250
Phlogopite, *see* Association of tin with.
Phœnicia:
Borlase on early tin trade of 1381, 1382
Edmonds on tin trade with Cornwall 1389
James, on ancient tin trade of 1399
Kenrick on early tin trade with Britain 1400
Lewis on sources of tin used in 1401
Rawlinson on Phœnician colonies in Andalusia, Spain, and in the Scilly Islands 1410
Saunders on route traversed in tin trade with Britain 1414
Sources of tin used in 744, 1401
Tin trade of 1380, 1382, 1389, 1399, 1400, 1401, 1414, 1418
Wray on source of tin used in 744
Phosphorus, *see* Association of tin with.
Pieux, *see* France, Manche.
Pihra, *see* India, Chota Nagpur.
Pike, E. R. 715
Pikedale field, *see* Queensland.
Pilbarra, *see* Western Australia.
Pilot Range, *see* Victoria.
Pilz, R. 1040
Pioneer, *see* Tasmania.

Reference Number

Piriac, *see* France, Lower Loire.
Pirsson, L. V. 1635
Pitkäranta, *see* Finland.
Pittman, Edward F. 834, 835
Place, John 716
Placer deposits, dredging and sluicing of 1578
Plagioclase, *see* Association of tin with.
Platinum:
  Associated with tin, *see* Association of tin with.
  Bechamp and Saintpierre on separation of gold and platinum from tin and antimony 1445
  Boucard on separation of gold and platinum from tin and antimony, 1455
  Campagne on mines of 1309
  Carne on source of platinum in beach sands of New South Wales... 809
  Compound of tin, oxygen, and platinum 1475
  de Koninch and Lecrenier on the qualitative separation of gold and platinum from arsenic, antimony, and tin 1474
  Delachanal and Mermet on a compound of tin, platinum, and oxygen. 1475
  Elsner on the separation of gold and platinum from tin and arsenic.. 1486
  Mingaye on occurrence in beach sands of New South Wales 831
  New South Wales 809
  Separation from gold, tin, and antimony 1445, 1455
  Separation from gold, tin, antimony, and arsenic 1474
  Separation from gold, tin, and arsenic 1486
  Used to effect complete reduction of tin 1583
Platt, Franklin (McCreath, A. S., and) 1243
Platte, Gabriel 1551
Platten, *see* Bohemia.
Plattner, C. A. 1552
Playford, E. C. 861a
Plinius, Caius 1408
Pliocene terraces in Cornwall containing deposits of tin and wolfram... 333
Plumas County, *see* California.
Plumbostannite, Raimondi on the new mineral 870
Plummer, John 56, 836, 837, 1121a, 1698
Plumose muscovite, *see* Association of tin with.
Poebel, *see* Bohemia.
Polgooth mine, *see* Cornwall.
Polwhele, R. 1409
Pontevedra, *see* Spain.
Pontgibaud, *see* France, Puy-de-Dome.
Poolamacca, *see* New South Wales, Silverton district.
Poopo Lake, *see* Bolivia.
Port Clarence, *see* Alaska.
Port Darwin, *see* Northern Territory.
Port Douglas district, *see* Queensland.

Reference Number

Porth, *see* England.
Porth Ledden Mills, *see* Cornwall.
Port Pegasus district, *see* New Zealand.
Portugal, tin in.....1027, 1286
D'Achiardi on tin in..... 1313
Beck on tin in.....1299, 1300
Breidenbach on tin in..... 873
Brown on tin in.....1307, 1308
Calderon on tin in..... 1029
Eschwege on tin in..... 874
Fawns on tin in..... 1321
Fuchs and de Launay on tin in..... 1323
Heale on tin mines of São Martinho and Montesinhos in Tras os Montes..... 875
de Launay (Fuchs and) on tin in..... 1323
Louis on tin in..... 1340
Louis (Phillips and) on tin in..... 1350
Montesinhos, tin in..... 875
Phillips and Louis on tin in..... 1350
Sandinha, tin near Goes in..... 872
São Martinho, tin in..... 875
Tras os Montes, tin in..... 875
See also Europe.
Poscovi, *see* Bolivia.
Pošepný, Franz..... 1351
Posewitz, Th.....112, 134, 300, 301, 302
Posth, C..... 869
Potgietersrust, *see* Transvaal.
Potosi, *see* Bolivia.
Potrillos, *see* Mexico, Durango.
Pozoconi Mountain, *see* Bolivia.
Poussin, *see* Malay Peninsula, Perak.
Praagh, L. V..... 1186
Pratt, Joseph Hyde.....251, 1217
Pratt, J. H. (Struthers, Joseph, and).....1020, 1220, 1364
Pratt, Joseph Hyde, and Sterrett, Douglas B..... 252
Pretoria, *see* Transvaal.
Preumont, G.....175, 176
Prior, G. L..... 1054
Prior, G. T..... 1636
Production of tin:
Africa, 1903 1347
Alabama, 1894 1357
Alaska, 1901 1292
Alaska, 1903..... 1347
Alaska, Seward Peninsula, through 1908..... 28b

Production of tin—Continued. Reference Number
Australasia, 1890 ... 1677
1899–1900 ... 48
Australia, 1874–1875 ... 49
1877–1878 ... 59
1881 ... 1412
1883 ... 1681
1891 ... 1344
1903 ... 54, 1347
1903–1904 ... 1679
1904 and 1905 ... 1698
Austria, 1903 ... 70, 1347
Banka, history, prices, etc ... 113
1880–1892 ... 83
1881 ... 1412
1881–1906 ... 1674
1883 ... 1681
1887 ... 1362
To 1897 ... 79
1897–1898 ... 80
Billiton ... 134
1854–1874 ... 123
1880–1892 ... 83
1881 ... 1412
1883 ... 1681
1887 ... 1362
1896–1906 ... 1674
To 1897 ... 79
Bohemia, 1891 ... 1344
Bolivia, ... 138, 142, 146, 167, 168, 180
1883 ... 1681
1891 ... 1344
1897–1909 ... 148g
1901 ... 1292
1901–1902 ... 166
1903 ... 170, 1347
1906 and 1907 ... 148a
1908 ... 148d
1909 ... 148b, 148c, 148e, 148f
Near Tupiza ... 144
Oruro, 1903–1904 ... 145
Burmah, Mergui district, 1889 ... 185
Tenasserim, 1889–1893 ... 195
California, 1889 ... 1695
To 1892 ... 213
1894 ... 1357
San Jacinto mine, 1891, giving gross value ... 210

Production of tin—Continued. Reference Number
China, 1881 ... 1412
Cornwall, 1201–1800 ... 1680
14th Century ... 1403
1742–1891 ... 336
1818–1887 ... 1669
1843 ... 483
1858–1868 ... 413
1861 ... 490
1864 ... 1699
1864–1873 ... 1687
1869 ... 414
1873–1883 ... 1681
1891 ... 1344
To 1906 ... 1693
To 1908 ... 427
1908 output and value ... 329b
1909 ... 329e
Average production of mines, 1846 ... 412
Balleswidden mine, 1837–1873 ... 451
Dolcoath mine, 1870 ... 469
1897–1901 ... 327
1898 ... 323
1900 ... 324, 326
General notes on 1887 ... 389
Huel Wherry, to 1818 ... 396
Lands End, 1852–1907 ... 448
Method of increasing output ... 472
Old Wheal Vor to 1870 ... 394
Devon, 1201–1800 ... 1680
1858–1868 ... 413
1864 ... 1699
1869 ... 414
1909 ... 329e
East Indies, 1872 to date ... 1689
1887 ... 1362
England, 1881 ... 1412
7 centuries to 1892 ... 1385
1853–1906 ... 1688
1882–1897 ... 1685
1893–1907 ... 329d
1901 ... 1292
1902 ... 436
1903 ... 437, 1347

roduction of tin—Continued. Reference Number
Finland, 1891 ... 1344
Pitkäranta, 1887–1889 ... 1691, 1692
France, 1901 ... 1292
Gray on ... 1325
Germany, 1903 ... 1347
Scrap tin ... 1497a, 1511
Great Britain, *see* England.
India, 1904 ... 588
Italy, 1876–1880 ... 623
Japan, 1892–1902 ... 1672
Bungo province, Kiura mine, 1848–1860 ... 630
Bungo and Satsuma, estimate, 1878 ... 631
Taniyama, 1890 ... 635
Maine, 1894 ... 1357
Malacca, 1881 ... 1412
1883 ... 1681
Malay Peninsula, 1876–1884 ... 695
1886 ... 706
1891 ... 657, 1344
1900 ... 666
1901 ... 666, 1292
1902 ... 667, 708
1903 ... 681, 692, 708, 1347
1904 ... 671, 691, 693
1905 ... 672
1906 ... 675, 733
1908 ... 730
Perak, 1896 ... 660
Quotations for tin product of ... 1675
Straits Settlements, 1896–1897 ... 662
1899 ... 1340
Malay states, *see* Malay Peninsula.
Mexico, 1891 ... 1344
1903 ... 1347
San Luis Potosi, 1901 ... 780
New South Wales, 1864 ... 806
1872–1875 ... 838
1875–1906 ... 1676
1875 to date ... 819
1885 ... 818
1886–1887, 1890–1891, 1894, 1895–1896 ... 815
1887 ... 1362
1890 ... 1677
1900–1904 ... 843
1901 ... 1292

Production of tin: New South Wales—Continued. Reference Number
1902 832
1903–1904 1679
Vegetable Creek, 1872–1876 822
To 1879 824
North Carolina 251, 252
1894 1357
1903 1220
Northern Territory, 1901 1292
Perak, 1893 732
1894 747
Tambun mine, 1904 670
Queensland, 1864 806
1872–1896 939
1887 1362
1890 1677
1898 936
1899 920
1900 921
1901 1292
1903–1904 1679
1904 922
1904 937
1904 ..... 884, 922, 937
Herberton district, 1895 919
1895–1896 932
1904 882
Vulcan mine, 1906 885
Herberton field, 1883–1894 43
Kangaroo Hills, 1904 929
Pikedale, 1904 933
Stanthorpe, 1904 933
Russia, 1888–1890 941
1885–1889 ..... 1690, 1691, 1692
Saxony, 1891 1344
Scrap tin 1497a
South Australia, 1901 1292
1903–1904 1679
South Carolina 251, 252
1903 1220
South Dakota, 1889 1695
1894 1357
1904 1018
Spain, 1891 1344
1896 to date 1684
Straits Settlements, *see* Malay Peninsula.

Production of tin—Continued. Reference Number
Swaziland, Ryan Tin Co., 1896....1046, 1056
Tasmania, 1875.... 1058
1877–1878.... 59
1878.... 1116
1880–1905.... 1673
1881.... 1412
1890.... 1677
1891.... 1344
To 1892.... 1118
1896–1897.... 1124
Through 1897....1128
1899.... 1065
1900–1901.... 1067
1901.... 1292
1903–1904....1077, 1679
Mount Bischoff, 1873–1877.... 1115
To 1900.... 1140
1903.... 1069
Transvaal, Rooiberg, to 1909....1185a
Tuscany to 1894.... 628
United States, 1890.... 1319
1904.... 1217
1905–1907....1209, 1210, 1211
Scrap tin....1497a
Victoria, 1873–1877, 1885–1888, and 1890 to date.... 1697
1890.... 1677
1899 to date.... 1222
1903-1904.... 1679
Western Australia.... 1671
1900.... 1261
1901....1254, 1255, 1266, 1292
1902.... 1266
To 1903.... 1264
1903–1904.... 1679
1904.... 1671
1907.... 1269
World, 1854.... 1701
1864–1873.... 1687
1874 to date.... 1683
1879–1881.... 1700
To 1880.... 1388
1881–1890.... 1682
1885–1899.... 1670
1890 to date.... 1694
1891.... 1344

Production of tin: World—Continued. Reference Number
1892 1372
1892 to date 1696
1894 1283
1897 1285
1898 1287
1899 1340
1900 1290
1903 ..... 1326, 1364
1904 1217
1905 1320
1905–1907 ..... 1209, 1210, 1211
1910 ..... 1298d
See references Nos. 1669-1707.
Prospecting, Wray on tables for checking accuracy of bore holes in alluvial tin prospecting 746
Providence mines, *see* Cornwall.
Provis, Richard (Kayser, H. W., and) 1102
Pryce, William 444, 1352
Pseudomorphs, cassiterite after feldspar 478, 479, 1597, 1603, 1632, 1638
Cassiterite after sulpho-stannites 1630
Headden on cause of tin pseudomorphs in the Black Hills, South Dakota 1616
Pueblo, *see* Mexico.
Puig y Larraz, D. Gabriel 1041
Puket, *see* Siam.
Punitaqui, *see* Chili.
Punnett, H. Macaulay 177, 445
Puno, *see* Peru.
Pusch, Geo. G. 949
Puy-de-Dome, *see* France.
Pyrite, *see* Association of tin with.
Pyrite-blende ores, Beck on occurrence at Schwartzenberg, Germany 530
Dalmer on origin of in the Altenberg-Graupen district of Germany .. 542
Pyrolusite, *see* Association of tin with.
Pyrrhotite, *see* Association of tin with.

Q

Qualla Lumpor, *see* Malay Peninsula, Kuala Lumpur.
Quartz, Daubrée on artificial production of 1601
Replaced by SnO_2 in Cornwall 357
Tin oxide after quartz and allophane in Cornwall 1629
See Association of tin with.
Quebec, Osann on tin at Graphite City in the Ottawa Valley 230

Reference Number

Queensland, tin in....45, 1290, 1292, 1298c
Annan River tin field.... 896
Babington on the Herberton tin field.... 886
Bain on the Tate tin mines.... 887
Ball on a comparison of mining and milling methods with those of Cornwall.... 331a
On Crows Nest tin deposits.... 888
On the King of the Ranges mine at Watsonville.... 891a
On tin along the Currumbin-Coolangatta beach.... 891
On tin in the Gayndah district.... 890
On tin in the Stanthorpe district.... 889
On treatment of tin ores at Irvinebank.... 891b
Barren Waters, tin at.... 939
Beer on tin in.... 806
Benedict on tin deposits of....47, 1301
Bloomfield, tin at.... 939
Brown on tin in....1307, 1308
Calcifer, tin at.... 935
California Creek, tin on....895, 927, 935
Cameron on the Annan River tin field, Cooktown district.... 896
On the Herberton field.... 895
On tin in the Kangaroo Hills.... 893
On Stannary Hills tin deposits.... 892
On tin on Thompsons Creek and in the Herberton district.... 894
Chillagoe, tin at.... 935
Clarke on tin mines in the Devonian of.... 814
Cleveland on tin dressing at Stannary Hills.... 897
Clotten on tin in Herberton district, on Wild River, at Watsonville, Irvinebank, and in Silver Valley.... 898
Coghlan on tin in....1677, 1679
Cooktown district, tin in....896, 917, 920
Coolgarra district, tin in....895, 926, 927
Crows Nest tin deposits.... 888
Currumbin-Coolangatta Beach, tin on.... 891
Cusack on Running Creek camp, Ravenswood fields.... 899
D'Achiardi on tin in.... 1313
Daintree on tin on Severn River.... 900
Davies on tin in.... 1317
Day on tin in.... 1318
Dowel on tin in the Herberton district.... 901
Dry River, silver mines on.... 916
Dunstan on Lancelot mine in Silver Valley.... 902
On Stannhills tin fields....904, 905
On tin with monazite at mouth of Tweed River.... 903
Edlinger on the Herberton district.... 906

Queensland—Continued. Reference Number

English on tin at Stanthorpe ... 50
Eureka Creek district, tin in ... 895, 925, 927
Fawns on tin in ... 1339
Fossilbrook, tin on ... 927
Fryar on tin in ... 907
Gayndah district, tin in ... 890
Glenlinedale, tin at ... 927
Gregory on tin in ... 908
On tin on Severn River ... 909
Haldane on the Herberton district ... 910, 911
On the Walsh and Tinaroo field ... 911
Herberton district, tin in ... 43, 876, 878, 881, 882, 885, 886, 894, 895, 898, 901, 906, 910, 911, 916, 919, 920, 927, 931, 932, 934, 935, 938, 939
Silver Valley, Lancelot lode in ... 881, 898, 902, 938
Vulcan mine ... 876, 885
Hopkinson River, tin on ... 940
Horsley on tin in the Kangaroo Hills and Star River fields ... 912
Hume on tin in ... 913
Irvinebank district, tin in ... 876, 895, 898, 927, 935, 939
Treatment of tin ores in ... 891b
Jack on silver mines on Dry River ... 916
On tin near Cooktown ... 917
On tin in Herberton, Western, and Thompsons Creek districts ... 916
On tin in the Kangaroo Hills, at Mount Brown, and on Running River ... 918
On tin in Stanthorpe district ... 915
On Wild River tin mines ... 914
Kangaroo Hills, tin in the ... 893, 912, 918, 920, 929
King of the Ranges mine ... 891a
Koorboora district, tin in ... 895, 927
Lions Den, tin in ... 896
Lock on tin in ... 1338
Louis on tin in ... 1340
Louis (Phillips and) on tin in ... 1350e
Macdonald on tin in ... 921, 922, 923, 924
On Herberton, Kangaroo Hills, Cooktown, Stanthorpe, Ravenswood, Palmer, and Port Douglas tin districts ... 920
Maclaren on Stannary Hills, Eureka Creek, and Watsonville districts ... 925
Maitland on the Coolgarra tin mines ... 926
Mance on tin mining during 1905 ... 52
Montalbion, tin at ... 935
Mount Amos, tin on ... 896
Mount Brown, tin at ... 918
Mount Leswell, tin on ... 896
Muldiva, tin at ... 935

Queensland—Continued. Reference Number
Munday on tin mining in and around Herberton..... 927
Myola, geological notes on..... 935
Newellton district, tin in..... 895
Newland on tin in.....928, 1346
Newman on Kangaroo Hills mineral field..... 929
Newton on metalliferous minerals of..... 55
Nicholas on Stannary Hills mines..... 929a
Palmer district, tin in.....920, 939
Palmer River, tin on..... 940
Pascoe River, tin on..... 939
Phillips and Louis on tin in..... 1350
Pikedale field, tin in..... 933
Port Douglas district, tin in.....920, 937
Ravenswood district, tin in..... 920
Tin on Running River 899
Reids Creek, tin near.....880, 895
Reyer on tin in..... 1354
Rolker on tin in..... 1357
Running River, tin on.....899, 918
Russell on Walsh and Tinaroo mineral field..... 930
Sellheim on tin of Herberton and other districts.....931, 932
Severn River, tin on.....900, 909
Short on Stanthorpe and Pikedale fields..... 933
Skertchly on geology near Stanthorpe and Warwick..... 936
On Herberton tin lead..... 934
On tin mines at Watsonville, Herberton, Montalbion, Irvinebank, etc..... 935
Smiths Creek mine, tin in..... 895
Smyth on tin in..... 1362
Staines on Port Douglas district..... 937
Stannary Hills, report, 1909..... 929a
Tin deposits.....892, 897, 925
Stannhills tin fields.....904, 905
Stanthorpe, tin at.....50, 883, 889, 915, 920, 933, 936, 939
Star River field, tin in.....912, 939
Sterling on geology and mining in Silver Valley, Herberton..... 938
Tate tin mines..... 887
Tate River, tin on.....927, 935
Thompsons Creek, tin on.....894, 916
Tinaroo (Walsh and) field, tin in.....911, 930
Tweed River, tin at mouth of..... 903
Walsh and Tinaroo field, tin in.....911, 930
Warwick, geology near..... 936
Watsonville district, tin in.....895, 898, 925, 927, 935
King of the Ranges mine 891a

Queensland—Continued. Reference Number
Weedon on tin on the Pascoe River, at Bloomfield, at Palmer, Barren Waters, Herberton, Irvinebank, Star River, and Stanthorpe..... 939
Western district, tin in..... 916
Wild River, tin on.....898, 914
William on tin along Hopkinson and Palmer rivers..... 940
Williams on tin mining and milling in..... 940a
See also Australia.
Queretaro, *see* Mexico.
Quicksilver, Emmons on occurrence in United States and genesis of minerals of 1206
Oppert on in Hoang-hai, Korea..... 640
World statistics since 1890..... 1694
See Cinnabar under "Association of tin with."
Quimsa Cruz, *see* Bolivia.
Quinsachata, *see* Bolivia.

R

R————, N..... 1218
Raffles, Thos. S..... 113
Rahman, *see* Siam.
Raimondi, A.....870, 1636a
Rammelsberg, C..... 1637
de Rance, Charles E..... 446
Ranft, Theod. 1122
Rangeh, *see* Siam.
Rant, H. F. E..... 135
Rapri, *see* Siam.
Rashleigh, P..... 447
Rath, G. von (Hertel, Paul, and)..... 625
Rath, M. J. von..... 1123
Rathborne, Ambrose B..... 717
Ratburi (East Coast), *see* Siam.
Ravenswood fields, *see* Queensland.
Rawdon, *see* Nova Scotia, Lunenberg County.
Rawhide Buttes, *see* Wyoming.
Rawlinson, George..... 1410
Rawson, S. G..... 1553
Ray, John..... 1554
Raymond, R. W.....787a, 1219
Realgar, Hennecke on occurrence in Persia..... 864
Recknagel 1186a
Recknagel, R.....1186b
Red River, *see* Cornwall.
Redruth, *see* Cornwall.

efining of tin: Reference Number
Cowper on electrolytic methods ... 1471
Delvaux de Fenffe on ... 1476
Dussauce on ... 1482
Graham on ... 1324
Hawkins on ... 1500
Platte on ... 1551
Sexton on methods in Cornwall ... 1361
Thiollier on refining of tin in Cornwall ... 1579
Weeks on ... 1372
eid, Clement, and Flett, J. S. ... 448
eid, Clement, and Scrivenor, J. B. ... 449, 1638
eid, J. H. ... 838
eids Creek, *see* Queensland.
eilly, ... 1353
ein, J. J. ... 634
eistian mine, *see* England.
emarkable Mountains, *see* New Zealand.
enaud, G. P. A. ... 114, 115, 116
enison Bell, *see* Tasmania.
enong, *see* Siam.
ontovski ... 971
esources of tin, *see* Supply of tin.
estronguet Creek, *see* Cornwall.
euss, A. E. ... 562
eyer ... 1411
eyer, E. ... 57, 117, 303, 304, 450, 563, 564, 565, 566, 567, 1354, 1355, 1412
hodesia, *see* Transvaal.
hys, John ... 1413
ibadavia, *see* Spain, Orense.
ichards, Joseph ... 1555
ichards, Robert H. ... 1556
ichardson, G. B. ... 1170
iche, A. (Cahours, A., and) ... 1463, 1464
ichmond County, *see* New South Wales.
ichmond River, *see* New South Wales.
ichter, Karl ... 1356
ichter (Muller, H., and) ... 560
ichthofen, F. ... 783
ickard, Edgar ... 33, 1125
ickard, Thomas ... 450a
icketts, Louis D. ... 1276
iefel ... 1557
ingarooma Valley, *see* Tasmania.
ink, Henry ... 585
iotte, E. N. (Bailey, Gilbert E., and) ... 988
iouw Islands, *see* East Indies.

Reference Number

Riouw-Linga Archipelago, *see* East Indies.
Ritchie, W. 1126
Ritter, Carl 718
Roberts, Malcolm 178, 179
Robertson, J. R. M. 58
Robertson, W. B. 1244
Rockbridge County, *see* Virginia.
Roehrig (Crookes and) 1242
Roessler 221
Rolker, Chas. M. 305, 719, 1357
Roman tin workings, Henwood on 1327
de Romana, Edwardo A. L. 180
Roodepoort, *see* Transvaal.
Rooiberg, *see* Transvaal.
Rosales, Hy. 1234
Roscoe, H. E. (Schenck, E., Smith, R. A., and) 1568
Rose, H. 1558, 1559
Rosenbusch, H. 1639
Rosewarne, H. (Borlase, Wm. Copeland, and) 347
Rosewarne mine, *see* England.
Ross, D. 720
Ross mine, *see* South Carolina.
Rowe, Capt. James 1127
Rowe, Leonard 1560
Rowe, T. P., and Foster, C. LeNeve 451
Royle 200
Rücker, Anton 568
Rudler, F. W. 452
Rudra, Sarat C. 597
Rumbold, Wm. R. 3b, 180a, 721
Running River, *see* Queensland.
Rupert's drops, crystals behaving like 3b
Rusapi, *see* Transvaal, Rhodesia.
Russell, Murray 930
Russia, tin in 941-942
  Cotta on tin in 1312
  Hermann on tin in the Urals 945
  Koulibine on mineral production in 1885, 1887, and 1888–1889 ... 1690, 1691, 1692
  Phillips and Louis on tin in 1350
  Urals, tin in 945
  Wyborg, tin in 1690
  See also Finland, Siberia, and Europe.
Rutile, Deville on the artificial production of 1604
  See Association of tin with.
Ryan 1055
Ryan tin works, *see* Swaziland, Embabaan.

S

Reference Number

S————, W. H..... 1015
Saavedra, Bautista (Ballivian, M. V., and)..... 150
Sadisberg, *see* Saxony.
Sadisdorf, *see* Saxony.
Sadtler, B..... 1016
Sain Alto, *see* Mexico.
St. Agnes district, *see* Cornwall.
St. Austell, *see* Cornwall.
St. Helens district, *see* Tasmania.
St. Ives, *see* Cornwall.
St. Just, *see* Cornwall.
St. Leonard, *see* France, Haute Vienne.
St. Pauls Plains, *see* Tasmania.
St. Pauls River, *see* Tasmania.
Saintpierre, C. (Béchamp, A., and)..... 1445
Salak, *see* Malay Peninsula, Perak.
Salamanca, *see* Spain.
Salet, G..... 1561
Salinta, *see* East Indies.
Salmon 1562
Salmon, Arthur L..... 453
Salmon, H. C..... 454
Sambong Giri, *see* Banka.
Sampling, methods at Cape Prince of Wales, Alaska..... 25
Sam River, *see* New South Wales.
Sandall, S. A..... 1563
Sandberger, F..... .....569, 1358
Sandeman, J. J..... 1128
Sandinha, *see* Portugal.
Sandrycock, *see* England.
San Isidoro mine, *see* Spain, Carthagene.
San Jacinto, *see* California.
San Jose, *see* Bolivia.
San Juan Mountains, *see* Colorado.
San Luis Potosi, *see* Mexico.
San Roque mine, *see* Bolivia.
San Salvadora lode, *see* Bolivia.
Santa Barbara, *see* Mexico, Guanajuato.
Santa Maria del Rio, *see* Mexico, San Luis Potosi.
Santa Vela Cruz, *see* Bolivia.
Santiago, *see* Spain.
Santo Domingo, Garston on tin in Seybo and in the Higuei..... 954
São Martinho, *see* Portugal.
Sapphire, *see* Association of tin with.
Satsuma, *see* Japan.

Reference Number

Sauberg, *see* Saxony.
Saunders, C. D. 1414
Saunders, W. T. 722
Saxony, tin in 534, 536, 552, 573, 577, 1310, 1314, 1639
Altenberg, geology of the region near 1628
Smelting of tin at 1516
Tin at 512, 528, 529, 536, 537, 539, 540, 542, 549, 551, 563, 567, 573a, 1310, 1337
Annaberg, tin mine at 573a
Anaberg Revieren, tin deposits of 558
Beck on tin at Altenberg 529
On tin near Schwarzenberg 530
On tin in Zinnwald 1300
Berggiesshübel, tin near 557
Bonnard on tin in the Erzgebirge 534
Charleton on tin deposits of Altenberg and Zinnwald 1310
Charpentier on tin deposits at Altenberg and elsewhere in Saxony .. 536
Cotta on tin at Altenberg 537, 539
On tin at Altenberg, Zinnwald, Marienberg, Ehrenfriedersdorf, Geyer, Johanngeorgenstadt, and Eibenstock 540
On Freiberg ore deposits 538
Dalmer on tin in Altenberg-Graupen district 542
On tin in Schneeberg 543
On tin at Schwarzenberg in the Erzgebirge 544
Daubrée on tin in Saxony 1314
Davies on tin deposits of 1317
Ehrenfriedersdorf, tin in 540, 554, 567, 574
Eibenstock, tin in 540, 561, 564, 572
Erzgebirge, calcining of tin ore in 1658
Discrimination of granites in 564
Origin of tin deposits of 575
Silver-bismuth deposits in 578
Tin in 528, 529, 530, 534, 544, 547, 551a, 553, 555, 556, 564, 574, 575, 576, 577, 578
Foullon on tin in Zinnwald 1322
Freiberg, ore deposits of 538, 559, 560, 575
Friesleben on the Erzgebirge 547
Fuchs and de Launay on tin in 66
Gätzschmann on the history of tin mining in Freiberg 1391
Geyer, tin in 540, 549, 567, 574
Leier mine 573a
Groddeck on tin at Altenberg, Geyer, and Zinnwald 549
Johanngeorgenstadt, tin in 540, 561, 578
Kersten on tin at Altenberg 1512
Klipstein on tin at Altenberg 551

Saxony—Continued. Reference Number
Kunhardt on the calcining of tin ore in the Erzgebirge 1658
Lampadius on smelting of tin at Altenberg 1516
de Lapparent on tin in 1335
de Launay (Fuchs and) on tin in 66
Lepsius on tin in the Erzgebirge 551a
Lindgren on tin deposits at Altenberg and Zinnwald 1337
Manès on tin in 552
Mann on tin in the Erzgebirge 553
Marienberg, tin in 540
Miklucho-Maclay on tin at Ehrenfriedersdorf 554
Müller on tin deposits of the Anaberg Revieren 558
On tin near Berggiesshübel 557
On tin in the Erzgebirge 555, 556
On tin deposits of the Freiberg Revieren 559
Müller and Richter on tin in the zinc-blende deposits of Freiberg 560
Nöggerath on the regions of Zinnwald and Altenberg 1628
Oppe on tin in Eibenstock, Johanngeorgenstadt, and Schneeberg 561
Rammelsberg on analyses of stannite from Zinnwald 1637
Reuss on tin in Zinnwald 562
Reyer on the discrimination of the granites in the Erzgebirge 564
On the geology of Eibenstock, Schwarzenberg, and the Erzgebirge 564
On tin mining in 565, 566, 567
On tin in Zinnwald and Altenberg 563
On tin in Zinnwald, Altenberg, Ehrenfriedersdorf, and Geyer 567
Richter (Müller and) on tin in Freiberg 560
Rosenbusch on tin in 1639
Sadisberg, tin mine at 573a
Sadisdorf, tin mine at 573a
Sauberg, tin mine at 573a
Schneeberg, tin in 543, 561, 573a
Schröder on tin in Eibenstock 572
Schultz on tin deposits of 573
Schwarzenberg, tin at 530, 544, 564
Singewald on tin deposits in the Erzgebirge 573a
Stelzner on the origin of the lead deposits of Freiberg and the tin deposits of the Erzgebirge 575
On tin in Ehrenfriedersdorf, Geyer, and the Erzgebirge 574
On tin in Freiberg and the Erzgebirge 575
Stelzner and Schertel on zinc-blende from Freiberg 1643
Sternberger on tin in the Erzgebirge 576
Telkin on tin mining in the Erzgebirge 577
Viebig on the silver-bismuth deposits in Johanngeorgenstadt, in the Erzgebirge 578
Woodward on tin ore specimens from 489a

Saxony—Continued. Reference Number
Zinnwald, analyses of stannite from ... 1637
Geology of the region around ... 1628
Tin in ... 540, 549, 562, 563, 567, 573a, 1300, 1310, 1322, 1337
See also Europe and Germany.
Scamander River, *see* Tasmania.
Schaeffer, Chas. A. ... 1017
Scheelite, Scrivenor on deposits in the tin bearing districts of Salak and Pahang, Malay Peninsula ... 726a
See Association of tin with.
Schertel, A. (Stelzner, A. W., and) ... 1643
Scheurer-Kestner, A. ... 1564, 1565
Schlackenwald, *see* Bohemia, Schlaggenwald.
Schlaggenwald, *see* Bohemia.
Schmidt, Albert ... 570, 571
Schnabel, Carl ... 794
Schneeberg, *see* Saxony.
Schneider, C. F. A. ... 306
Schönefeld, *see* Bohemia.
Schoultz-Ascheraden, G. von ... 950
Schouten Main, *see* Tasmania.
Schröder, M. ... 572
Schubarth, E. L. ... 1042
Schultz ... 573
Schultz, F. W. ... 1359
Schulz, Guillaume, and Paillette, Adrien ... 1043
Schultze, B. ... 1566
Schunck, Ed. ... 1567
Schunck, E., Smith, R. A., and Roscoe, H. E. ... 1568
Schuurman, J. A. ... 1415
Schwarzenberg, *see* Saxony.
Scilly Islands, tin and lead exported to Greece and Asia ... 1410
Borlase on ancient and present state of ... 1381
Plinius on tin from ... 1408
Rawlinson on Phœnician colonies in ... 1410
Scotland, Fawns on tin in ... 1320
Flett and Clough on tin in ... 955
See also Great Britain and Europe.
Scott, H. G. ... 962
Scrap tin:
Bergse process for recovery of ... 1442
Denmark, Copenhagen ... 1442
England ... 1438
Germany ... 1438, 1497a, 1511
Goldschmidt on recovery of tin from ... 1497a
Iron in ... 1555

Reference Number

Scrap tin—Continued.
Kershaw on electrolytic method of stripping tin from.....1511, 1511a
Malleable iron, used in manufacture of..... 1567
Nails made from..... 1573
Plants for the recovery of, located..... 1438
Recovery of.....1435, 1438, 1439, 1440, 1441, 1442b
At Copenhagen by Bergse process..... 1442
By electrolytic methods.....1439, 1440, 1441
In England..... 1438
Richards on saving tin and iron in..... 1555
Schultze on recovering tin from tin plate scrap.....1566
Schunck on recovering tin from tin plate scrap..... 1567
Smith (O.) on making nails from..... 1573
Wirtz on recovery of tin and zinc from..... 1584
Worsey on recovery of tin from..... 1586
Zinc in 1584
Scrivenor, J. B.....723, 724, 725, 726, 726a, 726b
Scrivenor, J. B. (Reid, Clement, and).....449, 1638
Sebastopol, *see* Victoria.
Sedgwick, Adam..... 1360
Seegrunde, *see* Germany.
Seiffen, *see* Germany.
Selama, *see* Malay Peninsula, Perak.
Selangor, *see* Malay Peninsula.
Sellheim, P. F.....931, 932
Sénez, L. 525
Serendah Valley, *see* Malay Peninsula, Selangor.
Severn River, *see* Queensland.
Seward Peninsula, *see* Alaska.
Sexton, A. Humbolt..... 1361
Seybo, *see* Santo Domingo.
Seymour, H. J..... 606
Shaw, A..... 1129
Shaw, B..... 1130
Shelbourne, *see* Nova Scotia, Lunenberg County.
Shepherd and Murphy's mine, *see* Tasmania, Bell Mount.
Short, C. H..... 933
Siak, *see* Sumatra.
Siam, tin in.....956-958
Bandon, tin in..... 960
Bangtaphan Langsuan, tin in..... 960
Blewett on tin on Junk-Ceylon or Salanga Island..... 959
Carter on tin in..... 960
Chaija, tin in .....960. *See* also Xaija
D'Achiardi on tin in..... 1313
Fawns on tin in..... 1320

Reference Number

Siam—Continued.
Fischer on tin in ... 961
Gascuel on tin in Nam-Patène, Laos ... 643
Jalar, tin in ... 960
Junk-Ceylon, tin on ... 959
Kedah, tin in ... 958, 960
Kelantan, tin in ... 960
Kra (West Coast), tin in ... 960
Lacroix on tin in Hin-boun, Laos ... 644
Lakon, tin in ... 960
Laos, tin in ... 516, 641, 642, 645
Hin-boun, tin at ... 644
Kammun, tin in ... 644
Nam-Patène, tin in ... 643
Nam Sak River, tin in ... 960
Pak-Phrëk, tin in ... 961
Panga, tin in ... 960
Pelatan on tin in Laos ... 645
Perlis, tin in ... 960
Puket, tin in ... 958, 960, 962
Rahman, tin in ... 960
Rangeh, tin in ... 960
Rapri, tin in ... 961
Ratburi (East Coast), tin in ... 960
Renong, tin in ... 960
Reyer on tin in ... 303, 1354
Salanga, tin on ... 959
Scott on tin in ... 962
Stul, tin in ... 960
Takuatung, tin in ... 960
Takupar, tin in ... 960
Trang, tin in ... 960
Xaija, tin in ... 961. *See* also Chaija
Xalang, tin in ... 961
Xumphon, tin in ... 961
See also Malay Peninsula and Asia.
Siberia, tin in ... 1290
Baikal region, tin in ... 969
D'Achiardi on tin in ... 1313
Fawns on tin in ... 1320
Fiedler on tin at the junction of the Onon and Ingoda rivers ... 943
Foniakoff on tin in ... 966
On tin in the Transbaikal ... 965
Glasser on tin on the Onon River ... 967
Hermann on tin in ... 968
Ingoda River, tin on ... 943

Siberia—Continued. Reference Number
Jeremejev on crystals of tinstone from the Jenisei region..... 1623
On tin in Transbaikal region..... 1622
Jenisei region, tinstone from the..... 1623
Korzoukhine on tin on the Onon River..... 976
Krusch on tin on the Onon River..... 947
Onon River, tin on.....963, 964, 967, 970, 971
Réontovski on tin on the Onon River..... 971
Transbaikal, tin in.....965, 970, 971
Transbaikal region, tin in..... 942
Yenisei, *see* Jenisei.
See also Russia and Asia.
Siderite, *see* Association of tin with.
Sierra de Catalan, *see* Mexico, Durango.
Silberberg, *see* Germany.
Silent Grove, *see* New South Wales.
Silicon, Berthelot on the action of oxygen on the compounds of tin, silicon, and boron..... 1448
Sillimanite, *see* Association of tin with.
Silurian, tin in slate of Silurian age in Spain.....1034, 1039
Tin ore in dikes cutting Silurian strata 158, 172
Stirling on tin in pegmatites cutting rocks of Upper Silurian age.. 1238
Twelvetrees on tin veins cutting rocks of Middle Silurian age in Tasmania 1148
Waller on tin in Devonian granite cutting sediments of Silurian age.. 1155
Silver:
Argentina, Salta..... 37
Associated with tin, *see* Association of tin with.
Ball on in Stanthorpe district, Queensland..... 889
Beck on occurrence at Schwartzenberg, Germany..... 530
Bohemia, Erzgebirge..... 578
Bolivia 144, 145, 152, 155, 164, 166, 171, 172
California, near Los Angeles..... 208
Campagne on mines of..... 1309
Castro on, in Salta, Argentina..... 37
Collins on presence in west of England..... 369
Cramer on precipitation of, out of tin..... 1472
Douglas on metallurgy of..... 1204
Emmons on occurrence in United States and genesis of minerals of.. 1206
England 369
Foniakoff on deposits in Siberia..... 965
Germany, Schwartzenberg..... 530
Jack on Kangaroo Hills mines, Queensland..... 918
Menniche on separation of, from tin ores..... 1534
Metallurgy of..... 1204
Moore on occurrence with tin in killas of St. Pauls Plains, Tasmania. 1114

Silver—Continued. Reference Number
Origin of minerals of ... 1206
Precipitation of, from tin ... 1472
Queensland ... 877, 889, 918, 932, 935, 936
Saxony, Erzgebirge ... 578
Sellheim on Herberton district, Queensland ... 932
Separation from tin ... 1472, 1534
Siberia ... 965
Skertchly on deposits in Queensland ... 935, 939
Sulphides of associated with tin in Bolivia ... 155
Tasmania ... 1079, 1114
United States ... 1206
Viebig on deposits of, in the Erzgebirge, Saxony ... 578
World statistics since 1890 ... 1694
Silver ores, *see* Association of tin with.
Silver sulphides, *see* Association of tin with.
Silver Crown district, *see* Wyoming.
Silver Hill, *see* Washington.
Silver Queen mine, *see* Tasmania, Zeehan.
Silverton district, *see* New South Wales.
Silver Valley, *see* Queensland, Herberton district.
Simmersbach, W. ... 1187
Simmons, Jesse ... 1018, 1019, 1019a
Simmons, Wm. ... 455
Simonin, L. ... 526, 1416
Simpang, *see* Sumatra.
Simpson, Edward S. ... 1267-1269
Simratari, *see* India, Chota Nagur.
Singapore, *see* Malay Peninsula.
Singewald, J. T., Jr. ... 573a
Singkap Island, *see* East Indies, Singkep.
Singkep, *see* East Indies.
Skene, A. J., and Smyth, R. B. ... 1235
Skertchly, Sydney B. J. ... 934, 935, 936
Skewes, Edward ... 456, 1662
Slack, W. E. ... 727
Slags, Bohne on recovery of tin from ... 1453
Brandenburg, Weyland, and Kempen on recovery of tin from ... 1456
Dykes on analyses of tin slags ... 1483
Thiollier on treatment of tin slags in Cornwall ... 1579
Slagle, Robert L. ... 1569
Slater, W. ... 1570
Slee, W. H. J. ... 839
Slimes (tin), Mackenzie on determination of tin in ... 1529
Hicks on methods of saving ... 1505
Treatment of, in Cornwall ... 1654, 1657
Slime tin (a variety of wood tin), Field on two specimens of ... 1607

	Reference Number
Sloan, Earl	253
Slocan district, *see* British Columbia.	
Smelting of tin	1294
Agricola on	1277
Banka	118, 1473, 1478, 1480
Billiton	118
Boase on methods in Cornwall	343
Bohemia	72
Bohne on recovery of tin from slags produced in	1453
Bolivia	153a
Bromley on methods and results with various tin ores at Santa Barbara, Mexico	766
Brown on costs in Bolivia	153a
Browne on Chinese method	1458
Charleton on methods used in	1310
Chinese methods	299, 694a, 711, 1458, 1473, 1489, 1523
Clark on methods in Tasmania	1076
Collett on methods in Malay Peninsula	681
Cornwall	312, 343, 432, 1361, 1425, 1518, 1554, 1576
Croockewit on Chinese methods in Banka	1473
Devon	312, 1425, 1576
Diest on methods in Banka	1478
Dijk on tin smelting in Banka	1480
Dussauce on	1482
Flower-Ellis on Chinese and European methods in Malay Peninsula,	694a, 1489
Germany, Altenberg deposits	528
Graham on	1324
Halse on methods at Los Cuevas, Mexico	773
Hampton on methods in Malay Peninsula	695
Hughes on tin smelting in the Malay Peninsula	1507
Latta on tin smelting at Mt. Bischoff, Tasmania	1517
Le Grice on "Jew's House" at Trereife, near Penzance, Cornwall	1518
Levy and Ewen on waste products of	1521a
Louis on smelting in shaft and reverberatory furnaces	1523
Malacca	299
Malay Peninsula	681, 694a, 695, 716, 1489, 1507
McKillop and Ellis on tin smelting at Pulo Brani, Singapore	1530
Merret on methods in Cornwall	432
Mexico	766, 773, 781
Nevius on methods at Sain Alto, Mexico	781
Newbold on Malay and Chinese methods in Malacca	299
Owen on Chinese methods in Perak	711
Perak	711, 715
Pike on methods in Perak	715
Place on methods in Malay Peninsula	716

Smelting of tin—Continued. Reference Number
Pryce on 444
Ray on tin smelting in Cornwall 1554
Sexton on reverberatory methods in Cornwall and Singapore 1361
Singapore 1361, 1530
Tasmania 1076, 1517
Taylor on smelting of tin ores in Cornwall and Devon 1576
Van der Wyck on methods in Banka and Billiton 118
Vogelsang on methods in Schlaggenwald, Bohemia 72
Weeks on 1372
Worth on smelting and sale of tin and copper in Devon and Cornwall (historical) 1425
See also Assays of tin, dressing of tin, metallurgy of tin, refining of tin.
See references Nos. 1428-1587.
Smirke, Edward 1417
Smith, Aquila 607
Smith, George 1418
Smith, J. Lawrence 1571, 1572
Smith, Oberlin 1573
Smith, R. A., and Roscoe, H. E. (Schenck, E., and) 1568
Smiths Creek mine, *see* Queensland.
Smyth, R. Brough 1236, 1237
Smyth, R. B. (Skene, A. J., and) 1235
Smyth, Warington W. 457, 1362
Snow, A. B. 201
Soekadana, *see* Borneo, Sukadana.
Soengei Liat district, *see* Banka.
Soengeiselan district, *see* Banka.
Solder, Schultz on production and application of 1359
Solly, R. H. 1640
Somero, *see* Finland.
Somerset, De La Beche on tin in 376
Foster on tin in 382
See also England.
Sonora, *see* Mexico.
South Africa, tin in 1045, 1047, 1285
Lock on tin in 1338
Newland on tin in 1347
See also Africa, Cape Colony, Rhodesia, Swaziland, Transvaal, etc.
South America, Benedict on tin in 1301
Louis on tin in 1340
Phillips and Louis on tin in 1350
See also Argentina, Bolivia, Chili, French Guiana, and Peru.
South Australia, tin in 45, 1290, 1292
Brown on gold at Tarcoola, Enterprise mine, and the Earea Dam tin find 974

South Australia—Continued. Reference Number
Brown on the Koetong tin field, Wodonga district ... 973
Coghlan on tin in ... 1679
Enterprise mine, gold at ... 974
Erea Dam, tin near ... 972, 974
Fawns on tin in northwest territory ... 1320
Koetong tin field ... 973
Mount Gunson mine, gold and copper at ... 974
Newton on metalliferous minerals of ... 55
Tarcoola, gold at ... 974
Wodonga district, tin in ... 973
See also Australia.
South Carolina, tin in ... 1196, 1298
Ball (S. M.) on the Ross mine ... 239a
Garrison on tin in ... 243, 1207
Graton on tin in ... 245, 246
Guenther on tin in ... 1326
Hess on tin in ... 247
Pratt on tin in ... 251
Pratt and Sterrett on tin in ... 252
Ross mine, tin in ... 238, 239a, 253
Sloan on the Ross mine ... 253
Struthers and Pratt on tin in ... 1364
See also Carolinas and United States.
South Dakota, tin in ... 1192, 1196, 1281
Bailey and Riotte on Harney Peak Tin Company ... 988
Bear Gulch district, tin in ... 1015
Beck on tin in ... 1299
On Etta mine ... 1300
Benedict on tin in ... 990, 1200, 1301
Benedict on tin near Custer City and in the Nigger Hill district ... 1275
Benedict on Harney Peak tin mines ... 989
Black Hills, assays of tin ores from ... 1466
Tantalite and tin in ... 976, 993, 996, 1009, 1017
Tin in ... 975, 976, 977, 979, 981, 982, 983, 991, 992, 1004, 1007, 1008, 1012, 1013, 1014, 1025, 1196, 1202, 1203a, 1207, 1208, 1213, 1318, 1364, 1466, 1506, 1616, 1646
Cleveland mine, tin in ... 1004
Custer County, tin in ... 1012
Elk Gulch, tin in ... 1008
Harney Peak ... 1019a
Northern Hills, tin in ... 1008, 1011
Peerless mine ... 1616
Pennington County, tin in ... 1012
Tinton, tin at ... 985, 987, 987a, 1009

South Dakota—Continued. Reference Number

Blake on the Geology of the Black Hills tin district..... 994
Blake on tantallite and columbite in the Black Hills.....993, 996
Blake on tin in Black Hills.....991, 993, 994, 995, 996, 997, 1202
Blake on Etta mine.....992, 994, 995, 996
Bob Ingersoll claim, tin on.....994, 996, 1009
Carpenter on tin in Black Hills.....998, 999, 1000, 1001
Carpenter and Headden on assays of tin ore from the Black Hills... 1466
Chance on tin in the Black Hills..... 1002
Childs on tin in Harney Peak district..... 1021
Claypole on tin in the Black Hills..... 1003
Custer City, tin west and south of..... 1275
Day on tin in the Black Hills.....1005, 1203a, 1318, 1319
On tin in Cleveland mine, Black Hills 1004
Dogtown, tin at..... 994
Emmens on tin in..... 1006
Etta mine 922, 994-996, 1009, 1017, 1300, 1616, 1646
Garrison on tin in the Black Hills.....1007, 1207
Gertie property 986, 1009
Guenther on tin in..... 1326
Harney Peak mine 979, 981, 982, 983, 988, 989, 1205
Harney Peak tin district.....1013, 1021, 1022
Harney Range, tin in..... 994
Headden on tin and tantalum in the Black Hills..... 1208
Headden on the Peerless and Etta tin mines, Black Hills..... 1616
Headden (Carpenter and) on tin in Black Hills..... 1466
Hess on tin, tungsten, and tantalum in..... 1009
Hofman on tin in Black Hills..... 1506
Irving on tin in Nigger Hill region..... 1010
Irving on tin in the northern Black Hills.....1010, 1011
Kemp on tin in Black Hills..... 1213
Lawrence County, tin in.....1016, 1020
M————, H., on tin in the Black Hills..... 1012
Morse on the Harney Peak tin mines..... 1013
Nigger Hill district, tin in.....980, 984, 985, 1010, 1275
O'Harra on tin in the Black Hills..... 1014
Pratt (Struthers and) on tin in northwestern Black Hills..... 1020
R———— on tin in..... 1218
Rolker on tin in..... 1357
Rosen on tin in..... 1000
Riotte (Bailey and) on Harney Peak Tin Company..... 988
S————, W. H., on tin in Bear Gulch district..... 1015
Sadtler on tin in the northwestern Black Hills..... 1016
Schaeffer on tin in Etta mine, Black Hills..... 1017
Simmons on tin in Black Hills.....1018, 1019
Struthers and Pratt on tin in Black Hills.....1020, 1364

	Reference Number
South Dakota—Continued.	
Thomas on tin in Harney Peak district	1021
Todd on tin in	1023
Thurlow on tin in Harney Peak district	1022
Ulke on tin in	1024
On Etta mine	1646
Vincent on tin in the Black Hills	1025
See also Dakota, Wyoming, and United States.	
South Crofty mine, *see* Cornwall.	
South Island, *see* New Zealand.	
South Wheal Breage mine, *see* Cornwall.	
Sowden, C	1131
Spain, tin in	1286
Andalusia, gold, silver, quicksilver, tin, lead, copper, and iron in	1410
Beck on tin in	1299, 1300
Borlase on tin in	1028
Brown on tin in	1307, 1308
Cáceres, tin in	1039
Cadiz, Lewis on tin in	1401
Calderón on tin in Galice and Portugal	1029
Calvert on tin in	1030
Cartagena, tin in	1040
Carthagene district, Marinera mine, tin in	1038
San Isidoro mine, tin in	1038
Superior Segunda mine, tin in	1038
Coquebert on tin in	1031
Coruña, tin in	1026
D'Achiardi on tin in	1313
Fawns on tin in	1320
Fuchs and de Launay on tin in	1323
Galæcia, Plinius on " white lead " from	1408
Galicia, tin in	1027, 1029, 1033, 1035
Garcia on tin in Salamanca	1032
Garland on tin in Galicia	1033
Gil y Maestre on tin in Salamanca	1034
Harmony on tin in Galicia	1035
de Launay (Fuchs and) on tin in	1323
Lock on tin in	1338
Louis on tin in	1340
Louis (Phillips and) on tin in	1350
Lozano on tin in Pontevedra	1036
Mallada on tin in	1037
Massart on tin in the " district de Carthagene "	1038
Orense, tin in	1026, 1027, 1044
Ribadavia, tin near	1044
Pacheco on tin in Cáceres	1039

Spain—Continued. Reference Number
Paillette (Schulz and) on tin in ... 1043
Phillips and Louis on tin in ... 1350
Pilz on tin in Cartagena ... 1040
Pontevedra, tin in ... 1026, 1036
Puig y Larraz on tin in Zamora ... 1041
Rawlinson on Phœnician colonies in Andalusia ... 1410
Salamanca, tin in ... 1026, 1032
Martinamor, tin at ... 1034
Terubias, tin at ... 1034
Santiago, tin at ... 1027
Schubarth on tin in ... 1042
Schulz and Paillette on tin in ... 1043
Thomas on tin near Ribadavia, Orense ... 1044
Zamora, tin at ... 1027, 1041
See also Europe.
"Sparable tin" in Cornwall ... 1640
Spargo, T. ... 1699
Sparry iron, *see* Association of tin with.
Spectrum of tin, Salet on ... 1561
Specular iron ore, *see* Association of tin with.
Spencer, L. J. ... 1641
Sphalerite, *see* Association of tin with.
Spodumene, *see* Association of tin with.
Spokane, *see* Washington.
Staines, Arthur ... 937
Stamping of tin ore in Cornwall ... 1654, 1656
Stanhope, *see* Tasmania.
Stanley River, *see* Tasmania.
Stannaries ... 1377, 1384, 1402, 1403
Stannaries act, Batten on ... 1377
Stannary Hills, *see* Queensland.
Stannhills, *see* Queensland.
Stannic oxide, Daubrée on artificial production of ... 1601
"Stannifer" on the Greenbushes tin fields ... 1270
Stannine, *see* Stannite.
Stannite:
Adger on analysis of an anomalous variety from Cornwall ... 1588
Associated with tin, *see* Association of tin with.
Conder on occurrence in Australasia ... 816
Dana on ... 1600
Greg and Lettsom on stannine ... 1614
Headden on alteration products of in the Black Hills, South Dakota ... 1616
Mallett on analysis of ... 1531
Petterd on gold and silver bearing stannite in Tasmania ... 1119
Rammelsberg on analyses of from Zinnwald and Cornwall ... 1637
Simpson, reference to ... 1268

Stannite—Continued. Reference Number
Spencer on crystals from Bolivia 1641
Stannine, *see* Greg and Lettsom under Stannite.
Stanthorpe, *see* Queensland.
Star River field, *see* Queensland.
Statistics 1669-1701
See also Production.
Steinman, G. 181
Stelzner, A. W. 182, 183, 458, 574, 575, 1642
Stelzner, A. W., and Schertel, A. 1643
Stephen, D. 59
Stephen, G. Milner 840
Stephens, Francis J. 459, 460, 598, 728
Stephens, Hugh 461
Sterling, James 938
Sternberger, Karl 576
Sterrett, Douglass B. (Pratt, J. H., and) 252
Stevens, Chas. 1363
Stevens, Horace J. 785
Stevens, R. P. 271
Stewart, D. S. S. 1188
Stewart Island, *see* New Zealand.
Steynsdorp Creek, *see* Transvaal.
Stibiotantalite, Simpson on presence in Greenbushes field, Western Australia 1267
See Association of tin with.
Stibnite, *see* Association of tin with.
Stirling, James 1238
Stockworks, German method of working 398
Stokes, Ralph (S. G.) 729, 730, 1132, 1133
Stokesite, described 1589
Stokesite, Hutchinson on a new mineral from Cornwall 1620
Stonier, G. A. 841
S(torms?), W. H. 1015
Straits Settlements, tin in 695, 1286, 1287
Day on tin in 1318
Louis on tin in 1340
Quotations on tin product of 1675
See also Malay Peninsula and Asia.
Streeruwitz, W. H. von 1171
Streng, A. 1574
Struthers, Joseph, and Pratt, Joseph Hyde 1020, 1220, 1364
Struve, H. von 951
Stul, *see* Siam.
Submarine mines, Hawkins on those of Cornwall 396
Sukadana, *see* Borneo.
Sukandana, *see* Borneo, Sukadana.

Reference Number

Sulphides, *see* Association of tin with.
Sulphur, Capitaine on action of tin, arsenic, antimony, and sulphur on the chloride of mercury 1465
Headden on compounds of, in an old Cornwall tin furnace..... 1617
Hennecke on occurrence in Persia 864
Sumatra:
Benedict on tin in.....281, 679, 1301
Fawns on tin in..... 1320
On tin in Siak.....1320
Fennema on tin in..... 293
On tin in the Boven Banjoe field of Palembang..... 292
Everwyn on tin in Simpang.....287, 291
On tin in Siak..... 290
Hamilton on tin in..... 294
Neeb on tin in..... 298
Palembang, Boven Banjoe tin field..... 292
Posewitz on tin in..... 301
Rolker on tin in Siak..... 305
Scrivenor on tin in Siak..... 726
Siak, tin in.....290, 305, 726, 1320
Simpang, tin in.....287, 291
Source of tin used by ancients..... 1405
See also East Indies.
Sungei Bâtang Pâdang, *see* Malay Peninsula, Perak.
Sungei Besi, *see* Malay Peninsula, Perak.
Sungei Bidor, *see* Malay Peninsula, Perak.
Sungei Kinta, *see* Malay Peninsula, Perak.
Sungei Lembing, *see* Malay Peninsula, Kuantan.
Sungei Riu, *see* Malay Peninsula, Jelebu.
Sungei Ujong, *see* Malay Peninsula, Malacca.
Suo, *see* Japan.
Superior segunda mine, *see* Spain, Carthagene.
Supply of tin (amount available for future mining):
Banka, 1897..... 79
Billiton, 1897..... 79
Cape Colony, 1906..... 233
Cornwall, 1873..... 364
1897 368
1906 441
1907 329
Devon, 1873..... 364
Great Britain, 1884..... 415
Kongo, 1906.....273, 274
Malay Peninsula, 1900..... 712
1901 665

Supply of tin—Continued. Reference Number
New South Wales, Inverell district, Tingja, 1906 803
Perak, 1881 684
Tasmania, Mount Bischoff, 1910 1121a
Mount Lyell, 1904 1072
World, 1908 1323a
Sources of supply, 1902 1363
Supply and demand, 1907 1308
Sources of supply 730
Swaziland, tin in 1045-1047, 1047a, 1286
Beck on tin near Embabaan 1299, 1300
Drakensberg mountains, tin in 1055
Embabaan, geology of region around 3
Tin near 2a, 3, 3d, 1047, 1048, 1050, 1051, 1052, 1055, 1300
Ryan tin works 1046, 1052, 1056
Embickelweni, tin near 1049
Flower-Ellis on tin fields in 694a
Forbes Reef tin deposits 3b
Hahn on tin at Embabaan 1048
Hampton on tin near Embickelweni 1049
Johnson on tin at Embabaan 2a
Jorissen on tin near Embabaan 1050
Lock on tin in 1338
de Launay on tin at Embabaan 3
Lyburn on tin near Embabaan 1051
Molengraaff on distorted cassiterite crystals from Embabaan 1052
On geology of region around Embabaan 1052
Newland on tin in 1053
Oshoek tin deposits 3b
Prior on tin in 1054
Rumbold on Oshoek and Forbes Reef tin deposits 3b
Ryan on tin in 1055. *See* also 1045
Smuts on tin in 1056
Transvaal border, tin along 1186
Usutu River, tin on 1055
Weston on tin mining and dressing at Embabaan 3d
See also Africa and South Africa.
Sweden, Davies on tin in 1317
See also Europe.
Swettenham, Frank 731
Swettenham, Frank A 732
Swinburne, U. P 1189
Swinburne, W. P 1189a
Symons, Brenton 462
Symons, R 463

[redacted]
[redacted] 1
[redacted]
[redacted] ..... [redacted]
[redacted] ..... [redacted]
[redacted]
[redacted]
[redacted]
[redacted]
[redacted]
[redacted] ..... [redacted]
[redacted] ..... [redacted]
[redacted]
[redacted]
[redacted]
[redacted]
[redacted]
[redacted] 1200
[redacted] 1217
[redacted]
[redacted] 1209
[redacted]
[redacted] 1208
[redacted]
[redacted] 1092
[redacted] 1105
[redacted] 1138
[redacted] 1106
[redacted] 1107
[redacted] 1145
[redacted] 1200, 1200
[redacted] 1142
[redacted] 1095, 1148
[redacted] 1201
[redacted] 47
[redacted] 1098
[redacted] 1135, 1155
[redacted] 1141, 1162
[redacted] 1129, 1130, 1136
[redacted] Blechoff 1075
[redacted] 1062, 1138, 1162
[redacted] 1062, 1064, 1106, 1125

Tasmania—Continued. Reference Number
Brookstead tin field 1091, 1106
Brothers' Home mine, tin in 1062, 1104
Brown on tin in 1307, 1308
Clark on tin in 1076, 1076a
Coghlan on tin in 1077, 1677, 1679
Conder on tin in 1078
On Stanley River tin field 1078a
On tin in the Oonah mine (Zeehan) and at Heemskirk 816
Cornwall mine, tin in 1076a
Counsel on tin in 1079
Coxs Bight tin field 1147
Cummings mine 1059
D'Achiardi on tin in 1313
Davey on Mount Bischoff tin mines 1080
Davies on tin in 1317
Day on tin in 1318
Derby, tin at 1062, 1104, 1125, 1139, 1298c
Dijk on tin in 1081, 1082
Dorset County, tin in 1109, 1141
Echo mine, tin in 1089
English on tin at Mount Bischoff 50
Fawns on tin in 1320
On Mount Bischoff mine 1083, 1084, 1320
Fircks on Mount Bischoff mine 1085
Foullon on tin in 1322
Georges Bay tin field 1162
Georges River, tin on 1111
Gladstone district, tin in 1106, 1130, 1143
Gould on tin in 1086
Government geologist's report on 1134
Grant on the Brookstead tin field 1091
On tin in eastern Tasmania 1090
On tin in the Echo mine 1089
On tin mining in the Blue Tier formations 1087, 1088, 1089
Great Mussel Roe River, tin on 1062
Gregory on the Mount Bischoff and other mines 1092
Groddeck on Mount Bischoff mine 1093
Hampton on Mount Bischoff mine 1049, 1094
Harcourt-Smith on tin in 1134
On tin at Bell Mount 1095
Heemskirk, tin at 816
Henry mine 1059
Hunt on Mount Bischoff tin mines 1096, 1097
Ireland on timbering at Ben Lomond 1098
Johnston on tin in 1099

Tasmania—Continued. Reference Number
Kayser on the Mount Bischoff mine....1100, 1101, 1152
Kayser and Provis on Mount Bischoff mine....1102
Klockman on Mount Bischoff mine....1103
Latta on smelting of tin ore at Mount Bischoff, Launceston....1517
Launceston, tin smelting works at....1517, 1525, 1535
Lewis on the Anchor mine....1105
On Brothers' Home Mining Company at Derby....1104
On the Gladstone district and other mines....1106
Lindgren on Mount Bischoff mine....1337
Lock on tin in....1338
Lottah claim....1089
Louis on smelting of tin at Mount Bischoff, Launceston....1525
On tin in....1340
Louis (Phillips and) on tin in....1350
Mackintosh River, tin on....1112
Mance on tin mining in 1905....52
Maynes mine....1076a
Meredith on tin from Mount Bischoff....1107
Middlesex district, tin in....1148
Millen on hydroelectric power plant at Mount Bischoff....1107a
On smelting of tin at Mount Bischoff, Launceston....1535
Montgomery on tin in....1110, 1111, 1113
On Blue Tier tin field....1108, 1109
On mineral fields near Zeehan....1112
Moon claim....1089
Moore on tin in killas of St. Pauls Plains....1114
Moorina, tin at....1062, 1130
Mount Bischoff mine..50, 63, 730, 1049, 1057, 1059, 1061, 1062, 1063, 1064, 1065, 1066, 1067, 1069, 1073, 1074, 1075, 1076a, 1080, 1083, 1084, 1085, 1092, 1093, 1094, 1096, 1097, 1100, 1101, 1102, 1103, 1106, 1107, 1110, 1113, 1115, 1117, 1122, 1123, 1126, 1127, 1128, 1129, 1130, 1131, 1133, 1140, 1149, 1150, 1151, 1152, 1159, 1160, 1162, 1163, 1298c, 1320, 1337, 1517, 1525, 1535
Dividends and future of....1121a
Hydroelectric power plant at....1107a
Mount Black, tin on....1112
Mount Cameron, tin at....1062
Mount Dundas, tin on....1112
Mount Heemskirk field....1068, 1106, 1112, 1130, 1156
Mount Lyell, tin near....1064, 1072
Mount Ramsay, tin on....1163
Mount Read, tin on....1112
Mount Zeehan, tin on....1112
Mufford on Mount Bischoff mine....1115
On tin mines in....1116

Tasmania—Continued. Reference Number
Newland on tin in 1346
Newman on Mount Bischoff mine 1117
On tin in 1059
Newton on mineral resources of 55
North Dundas, tin in 1064, 1071, 1157, 1158a
Oonah mine (Zeehan), tin in 816
Orient farm, tin on 1068
Ormuz mine, tin in 1062
Petterd on tin in 1118, 1120, 1121
On tin in Silver Queen mine, at Zeehan 1119
Petterd (Twelvetrees and) on Mount Bischoff dikes 1149
Phillips and Louis on tin in 1350
Pioneer, tin at 1062, 1070, 1106
Plummer on dividends paid by and future of Mount Bischoff mine 1121a
Provis (Kayser and) on Mount Bischoff mine 1102
Ranft on Mount Bischoff mine 1122
Rath on Mount Bischoff mine 1123
Rowe on Mount Bischoff mine 1127
Renison Bell mine, tin in 1064, 1146
Report of the Secretary for Mines 1124
Reyer on stream tin from 1411
On tin in 57, 1354
Rickard on tin in Briseis mine, at Derby 1125
Ringarooma Valley, tin in 1062, 1074, 1111, 1129, 1139, 1162
Ritchie on Mount Bischoff tin mine 1126
Rolker on tin in 1357
Rowe on Mount Bischoff tin mine 1127
St. Helens district, tin in 1153, 1154
St. Pauls Plains, tin in killas of 1114
St. Pauls River tin deposit 1135, 1137
Sandeman on Mount Bischoff mine and Blue Tier district 1128
Scamander River district, tin in 1153
Schouten Main, tin ore on 1144
Shaw on Mount Bischoff, Blue Tier, Ringarooma, Gladstone, etc., tin fields 1129, 1130
Snowden on Mount Bischoff mine 1131
Stanhope mine 1059
Stanley River tin field, tin in 1078a, 1112, 1158
Stephen on tin production, 1877–1878 59
Stokes on Mount Bischoff mine 729, 730, 1132, 1133
Thureau on Ben Lomond and St. Pauls River tin deposits 1135
On Blue Tier district 1136
Tregay on tin in 60

Tasmania—Continued. Reference Number
Twelvetrees on Arba mine at Branxholm ... 1138
On Badger tin mines ... 1145
On Bell Mount field ... 1142
On Bell Mount, Middlesex district ... 1148
On Blue Tier district ... 1141
On Coxs Bight tin field ... 1147
On Gladstone district ... 1143
On mineral fields between Waratah and Corinna ... 1140
On Renison Bell tin field ... 1146
On tin in ... 1134
On tin in Ringarooma Valley near Derby ... 1139
On tin on St. Pauls River near Avoca ... 1137
On tin ore on Schouten Main ... 1144
Twelvetrees and Petterd on Mount Bischoff dikes ... 1149
Twelvetrees and Ward on the Zeehan mining field ... 1149a
Ulrich on Mount Bischoff tin mine ... 1150, 1151
Waddington on Mount Bischoff tin mine ... 1152
Wallace on tin in ... 1134
Waller on Stanley River tin field ... 1158
On tin deposits of North Dundas ... 1157
On tin in Ben Lomond district ... 1155
On tin in Mount Heemskirk district ... 1156
On tin in Scamander River and St. Helens districts ... 1153
On tin in St. Helens district ... 1154
Waratah mine ... 1059, 1140
Ward on North Dundas tin field ... 1158a
Webster's workings, alluvial tin at ... 1140
Wellington on Mount Bischoff mine ... 1159
White River Bridge, alluvial tin at Ten Mile claim ... 1140
Wickham on Mount Bischoff mine ... 1160
On tin in ... 1161
Williams on the Zeehan mining field ... 1161a
Wilson on Mount Bischoff, Ringarooma, Branxholm, Georges Bay, and Blue Tier fields ... 1162
Wintle on tin in ... 1164
On Mount Bischoff mine and tin at Mount Ramsay ... 1163
Zeehan, mineral fields near ... 1112
Mining field in ... 1149a, 1161a
Silver Queen mine, stannite in ... 1119
See also Australia.
Tassin, Wirt ... 1365
Tatasi, *see* Bolivia.
Tate, Ralph ... 862
Tate mines, *see* Queensland.
Tate River, *see* Queensland.
Tavoy, *see* Burmah.

Reference Number

Taxco, *see* Mexico, Guerrero.
Tayler, J. W. 586
Taylor, Charles D. 464
Taylor J. 1663
Taylor, John 1419, 1576
Taylor, N. 842
Taylor, William 733
Teallite, Prior on a new sulphostannite of lead from Bolivia 1636
Tecca, *see* Malay Peninsula, Perak.
Telkin 577
Telom, *see* Malay Peninsula.
Temescal district, *see* California.
Tenasserim, *see* Burmah.
Tenison-Woods, J. E. 307, 734, 735, 736, 737, 863
Teplitz, *see* Bohemia.
Terrell, S. L. 1576a, 1664
Tertiary:
  Tin in 155, 182
  Tin in rhyolites of Tertiary age 751
  Tin with galena and pyrite in Tertiary tuffs 629
  Gascuel on tin in rocks of Tertiary age in Laos 643
  Lotti on tin deposits in Tertiary intrusives in Tuscany 627
  Seymour on cassiterite in Tertiary granite in Mourne Mountains, Ireland 606
Terubias, *see* Spain, Salamanca.
Teschemacher, J. E. 750
Texas, tin in 1281
  Burnet County, tin in 1169
  Chauvenet on tin in the Franklin Mountains 1164a
  Comstock on tin in central 1165, 1166, 1167, 1168
  Day on tin in 1203a
  Dumble on tin in Trans-Pecos 1169
  El Paso tin deposits 1170, 1172, 1216
  Franklin Mountains, tin in 1164a, 1169a, 1170, 1172
  Kemp on tin in 1213
  Lakes on tin prospect in Franklin Mountains 1169a
  Llano County, tin in 1168
  Mason County, tin in 1168, 1169
  Pavlov on tin deposits of El Paso 1216
  Richardson on tin in the Franklin Mountains 1170
  Rolker on tin in 1357
  Streeruwitz on tin in West Texas ores 1171
  Trans-Pecos, tin in 1169
  Weed on tin in Franklin Mountains 1172
  See United States.
Thaiping, *see* Malay Peninsula, Perak.

Reference Number

Theobald, W. ... 202
Thomas, C. ... 466
Thomas, Chas. ... 465, 1044, 1665
Thomas, Herbert ... 467
Thomas, Herbert H. ... 468
Thomas, Josiah ... 469, 470, 1021
Thomas, R. ... 471
Thomas, R. A. ... 472
Thomas, R. Arthur ... 1666
Thomas, Richard A. ... 473
Thomas, V. ... 1580
Thomas, Wm. ... 474
Thomas, Wm., and Burrow, J. C. ... 475
Thompsons Creek, *see* Queensland.
Thibault, P. J. ... 843, 844, 1577, 1578, 1644
Thiollier, M. A. ... 1579
Thistle mine, *see* New South Wales.
Thonard, Léon (Beco, Jean, and) ... 612
Thureau, G. ... 1135, 1136
Thurlow, Lord ... 1022
Tilde area, *see* Nigeria.
Timbarra, *see* New South Wales.
Timbering, Chaplin on methods in Cornwall ... 358
Ireland on method at Ben Lomond, Tasmania ... 1098
See also Mining of tin.
Tin:
Ages of the tin deposits of the world ... 1625
Artificial production of crystals of metallic tin ... 1626, 1645
Cry of ... 1521
Cry of, similar, in other metals ... 1481
Derivation of name ... 1412
Dimorphous form produced in manufacture of metallic tin crystals ... 1645
Effect of intense cold on ... 1492
de Launay on the ages of the tin deposits of the world ... 1625
Separation of tungsten ... 1575
Separation from arsenic, antimony, etc. ... 1445, 1447, 1455, 1459, 1465, 1467, 1474, 1477, 1485, 1486, 1495, 1503, 1553, 1558, 1559, 1572, 1585
See alloys of tin, analyses of tin, assaying of tin, assays of tin, association of tin with, chemistry of tin, crystallization of tin, dressing of tin, exportation of tin, financial side of tin, history of tin, importation of tin, metallurgy of tin, milling of tin, mineralogy of tin, minerals of tin, mining of tin, occurrence of tin, origin of tin, production of tin, refining of tin, scrap tin, smelting of tin, supply of tin (amount available for future mining), uses of tin, and the various minerals of tin.

Reference Number

Tinaroo, *see* Walsh and Tinaroo, under Queensland.
Tin bioxide, Ditte on some combinations of..... 1606
Tincroft mine, *see* Cornwall.
Tingha district, *see* New South Wales.
Tinogasta, *see* Argentina, Catamarca.
Tin ore, phosphorescent when heated..... 935
Tin oxide, after quartz and allophane in Cornwall..... 1629
Daubrée on artificial production of..... 1316
Deville on artificial production of.....1604, 1605
See also "Tin bioxide."
Tin plate:
Allan on production of "moire metallique" on.....1429
Flower on history of origin and process of tin plate trade..... 1390
Graham on..... 1324
Künzel on..... 1514
United States, industry in..... 1202
See Scrap tin.
Tin pyrites, *see* Stannite.
Tinton, *see* South Dakota, Black Hills.
Titanite, *see* Association of tin with.
Titanium, Daubrée on artificial production of..... 1601
See Association of tin with.
Toad's eye tin..... 356
"Toad's eye wood tin," Field on a variety of..... 1607
Toboali district, *see* Banka.
Todd, J. E..... 1023
Tomuko, *see* China, Yunnan.
Tongka Harbor, *see* Malay Peninsula.
Tonkin, Lacroix on tin in..... 516
Topaz, *see* Association of tin with.
Törnebohm, A. E..... 952
Totoral mine, *see* Bolivia.
Tourmaline, MacAlister on origin of tin and..... 1341
See Association of tin with.
Trang, *see* Siam.
Transbaikal region, *see* Siberia.
Trans-Pecos, *see* Texas.
Transvaal, tin in.....1173, 1176, 1177
Black Umbelosi River, tin on watershed of..... 1186
Bushveld near Pretoria, tin in the.....1175, 1180, 1181, 1182, 1186
Bushveld tin deposits 3b
Davey on Trans-Zambesian mining..... 1179
Doornhoek, tin at.....2a, 1178j, 1183c
Enkeldoorn district, tin in.....1180, 1184, 1186
Fawns on tin in..... 1320

Transvaal—Continued. Reference Number
Griffith on the Bushveld properties 1189
Groenvlei tin fields.....1178f, 1183a
Groenfontein tin plant.....1178b, 1178j
Hall on tin near Pretoria and Vlaklaagte.....1181, 1182
Johnson on tin near Potgietersrust..... 1183
On the Rooiberg, Weynek, Dornhoek, and Potgietersrust tin deposits 2a
Jorissen on intrusive granites in..... 1050
Kynaston on tin deposits of Zaaiplaats in the Waterberg district...1183b
Lawn on the Doornhoek mine.....1183c
Little Usutu River, tin on watershed of..... 1186
Lualaba, tin on..... 1174
Lyburn on minerals in..... 1051
Merensky on tin in Enkeldoorn district..... 1184
On Potgietersrust tin fields..... 1185
On tin deposits of Rooiberg, Warmbad, Nylstroom, and Potgietersrust 1184a
Mills-Davies on tin deposits of.....1185a
Newland on tin in..... 1053
Nylstroom, tin mining at.....1184a, 1185a
Occurrence in various districts of.....1178d
Potgietersrust, tin near.....1183, 1185, 1189
Tin district.....2a, 1178a, 1178b, 1184a, 1185a
Praagh on tin along Transvaal-Swaziland border and in Vlaklaagte and Enkeldoorn districts..... 1186
Pretoria district, tin in.....1175, 1180, 1181, 1182, 1187
Recknagel on the two deposits in the Rooiberg district.....1186a
Rhodesia, Rusapi, discovery of tin at.....1178k
Roodepoort tin deposit.....1183b
Rooiberg, tin at.....2a, 1178g, 1178i, 1178j, 1185a, 1186a
Rooiberg tin deposits.....3d, 1184a
Rumbold on Bushveld tin deposits..... 3b
Simmersbach on tin in Pretoria district..... 1187
Stewart on tin on the Great Letaba River, Zoutpansberg..... 1188
Steynsdorp Creek, tin on watershed of..... 1186
Stokes on tin in..... 730
Swaziland border, tin along..... 1186
Swinburne on tin at Zaaiplaats near Potgietersrust..... 1189
On Waterberg tin field.....1189a
Tin producing districts of.....1178c
Vlaklaagte, tin mine at.....1178, 1181, 1182, 1186
Warmbad tin district 1184a, 1185a
Waterberg, tin at.....1178g, 1178h, 1178l
Tin deposits 3d, 1183a, 1183b, 1189a
Weston on tin mining and dressing at Waterberg, Zaaiplaats, and Rooiberg 3d

Reference Number

Transvaal—Continued.
Weynek, tin at....2a, 1178g
Zaaiplaats tin deposits....3d, 1178e, 1178h, 1183a, 1183b
Zoutpansberg, tin on the Great Letaba River in.... 1188
Zwartkloof tin deposit.... 3d
See also Africa, Pretoria, and South Africa.
Tras, *see* Malay Peninsula, Telom.
Trasenster, Paul.... 1700
Tras os Montes, *see* Portugal.
Treacher, W. H.... 738
Trechmann, C. O.... 1645
Tredinnick, R.... 476
Tregaskis, James.... 477
Tregay, W....60, 1667
Treloy, *see* England.
Tremenheere, G. B....203, 205, 206
Tremenheere, G. B. (Lemon, Chas., and).... 196
Tremenheere, G. H.... 204
Tremenheere, H. Seymour.... 739
Tremolite, *see* Association of tin with.
Trenchard, H. G.... 844a
Trengganu, *see* Malay Peninsula, Tringganu.
Trereife, *see* Cornwall.
Tres Cruces, *see* Bolivia.
Trethellen tin works, *see* Cornwall.
Triassic, tin in veins in limestones of the.... 268
Tringanu, *see* Malay Peninsula, Tringganu.
Tringganu, *see* Malay Peninsula.
Triphyllite, *see* Association of tin with.
Tripolite, *see* Association of tin with.
Trojan war, Plinius on estimation of "white lead" during.... 1408
Tronoh, *see* Malay Peninsula, Perak.
Truro, *see* Cornwall.
Trüstedt, Otto.... 953
Tsementong, *see* China, Yunnan.
Tungstate of manganese and iron, *see* Association of tin with wolframite.
Tungsten:
Associated with tin, *see* Association of tin with.
Billiton.... 126a
Delvaux de Fenffe on use in iron and steel.... 1476
Fairibault on occurrence of, with tin in Nova Scotia.... 227
Hess on deposits of, with tin in South Dakota.... 1009
Menniche on separation of, from tin ores.... 1534
Nova Scotia.... 227
Sadtler on deposits of, with tin in the Black Hills, South Dakota.... 1016
Separation from tin....1534, 1575

Tungsten—Continued. Reference Number
South Dakota 1009, 1016
Talbott on the quantitative separation of tin and 1575
Tasmania 1095, 1148
Twelvetrees on deposits in tin bearing region, Tasmania 1148
Used with iron 1476
Tuscany, *see* Italy.
Tuscarora mines, *see* Nevada.
Tupiza, *see* Bolivia.
Tweed River, *see* Queensland.
Tweedy, W. M. 478, 479
Twelvetrees, W. H. 1137, 1138, 1139, 1140, 1141, 1142, 1143, 1144, 1145, 1146, 1147, 1148, 1148a
Twelvetrees, W. H., and Petterd, W. F. 1149
Twelvetrees, W. H., and Ward, L. Keith 1149a
Tylor, A. 1420
Tyre, tin a current commodity of commerce in 1380

U

Ubangi, *see* French Kongo.
Uelle, *see* French Kongo, Welle.
Ulke, Titus ..... 254, 1024, 1245, 1646. *See* also 1616
Ulrich, G. H. F. 845, 1150, 1151
Uncia vein, *see* Bolivia.
United Kingdom, *see* Great Britain, England, etc.
United States, tin in 1190, 1191, 1192, 1193, 1194, 1195, 1196, 1197, 1198, 1199, 1298b
Beck on tin in 1299, 1300
Benedict on tin in 1200
Blake on tin in 1201, 1202
Census report on tin in 1221
Day on tin in 1203
D'Achiardi on tin in 1313
Douglas on tin in 1204
Emmens on tin in 1205
Emmons on geological distribution of tin in 1206
Fawns on tin in 1320
Fuchs and de Launay on tin in 1323
Garrison on tin in 1207
Hess on tin in 1209, 1210, 1211
Importation of tin from Bolivia discussed 139
Kemp on tin in 1212, 1213
de Launay (Fuchs and) on tin in 1323
Leonhard on tin in 1214
Lesley on furnaces, forges, and rolling mills for iron in 793

United States—Continued. Reference Number
Lock on tin in..... 1338
Louis on tin in..... 1340
Newland on tin in..... 1346
Ohly on tin in..... 1215
Phillips and Louis on tin in..... 1350
Pratt on tin in..... 1217
R————, N., on tin in..... 1218
Raymond on tin in..... 1219
Rolker on tin in..... 1357
Scrap tin recovered in.....1497a
Struthers and Pratt on tin in..... 1220
Weeks on tin in..... 1372
Whitney on statistics of mineral production of..... 1701
See also Alabama, California, Colorado, Idaho, Maine, Massachusetts, Michigan, Missouri, Montana, Nevada, New Hampshire, New Jersey, North Carolina, Philippines, South Carolina, South Dakota, Texas, Virginia, Washington, and Wyoming.
Unwin, George..... 480
Upper Graupen, *see* Bohemia.
Upper Murray, *see* Victoria.
Upper Yarra, *see* Victoria.
Urals, *see* Russia.
Uralsk, *see* Asia.
Uranium, de Launay on occurrence with tin in France..... 518
See Association of tin with.
Uranium phosphate, *see* Association of tin with.
Ure's Dictionary..... 1366
Uses of tin:
Appleton on earliest American coin..... 1374
Baudot on..... 1378
Boerhaave on..... 1305
Coating inside of copper utensils in India..... 588
Feuchtwanger on..... 1321
Fuchs and de Launay on..... 1323
Graham on..... 1324
Jameson on..... 1621
Lakes on.....1334a
Perak, native uses..... 747
Salmon on..... 1562
Schultz on..... 1359
Sexton on..... 1361
Ussher, W. A. E., and MacAlister, D. A..... 481
Uwet district, *see* Nigeria.

V

Reference Number

Vale, Stephen S. 61
Valerio, *see* Italy, Tuscany, Monte Valerio.
Van der Wyck, O. H. 118
Van Hise, Charles Richard 1367
Vanning, Collins on its value as a mine test for tin ore 1469
  Pearce on losses in 1660
Van Ness, W. W., Jr. 254a
Van Osdel, Edgar B. 1580a
Vaulry, *see* France, Creuse.
Vay, *see* France, Lower Loire.
Vegetable Creek, *see* New South Wales.
Verbeek, R. D. M. 119, 136
Vercoe, Chas. 740
Vercoe, H. B. 741
Vesuvianite, *see* Association of tin with.
Vesuvius, *see* Virginia.
Veta Estaño, *see* Bolivia.
Viator 742
Victoria:
  Albany, stream tin near 50
  Beechworth, tin at 1233
  Benambra, Cudgewa district, tin in 1226
  Benedict on tin deposits of 41, 1301
  Berwick, tin at 1233
  Braché on tin at Eldorado 1224
  Bright, tin at 1233
  Bruthen, tin at Falls Church, near 1228
  Burrowa Creek, tin on 1233
  Corner Inlet, tin from 1232
  Coghlan on tin in 1677, 1679
  Cudgewa district, tin in 1226, 1229, 1233, 1237
  D'Achiardi on tin in 1313
  Davies on tin in 1317
  Dry Forest Creek, tin on 1233
  Eddy on tin on the Latrobe River, South Gippsland 1225
  Eldorado, tin mining at 1224
  English on tin near Ovens and Albany and in Gippsland 50
  Eskdale, tin at 1227, 1229
  Falls Church, near Bruthen, tin at 1228
  Fawns on tin in 1320
  Franklin, tin from 1232
  Gippsland, tin in 50, 1229, 1237
    Beenah, tin near 1223
    Franklin River, tin on 1230
    Latrobe River, tin on 1225, 1233, 1235
    Mount Singapore on Wilsons Promontory 1229

Victoria—Continued. Reference Number
Gregory on the Mount Cudgewa tin..... 1226
Herman on tin at Falls Church, near Bruthen..... 1228
On tin at Mitta Mitta, Eskdale, Tallandoon, and Mt. Elmo..... 1227
Kitson on tin in..... 1229
Louis (Phillips and) on tin in..... 1350
Mitta Mitta River, tin on.....1227, 1237
Mitta River Valley, tin on Wombat and Nine Mile creeks..... 1238
Mount Elmo, tin at..... 1227
Mount Fatique, tin on.....1233, 1235
Mount Singapore, tin at..... 1229
Mount Wills, tin at.....1229, 1231, 1234
Mount Wills Creek, tin near..... 1238
Murray on the Mount Wills tin field..... 1231
On tin in southwest Gippsland..... 1230
Murray, *see* Upper Murray.
Newbery on tin from Franklin, Corner Inlet, and Upper Murray.... 1232
Newton on metalliferous minerals of..... 55
Nicholas on tin at various localities in..... 1233
Northeastern district, Mount Cudgewa, tin at..... 1229
Eskdale, tin in.....1227, 1229, 1231, 1234
Pilot Range, tin in..... 1229
Mount Wills, tin at 1229, 1231, 1234
See also Mount Wills Creek.
Phillips and Louis on tin in..... 1350
Pilot Range, tin in..... 1229
Reyer on tin in..... 1354
Rolker on tin in..... 1357
Rosales on the Mount Wills tin field..... 1234
Sebastopol, discovery of tin at..... 43
Secretary for Mines and Water Supply, Annual Reports 1899 to date.. 1222
Skene and Smyth on tin on the Latrobe River and Mount Fatique... 1235
Smyth on tin on the Upper Murray River..... 1236
Smyth (Skene and) on tin on the Latrobe River and Mount Fatique.. 1235
Stirling on tin lodes at Wombat Creek..... 1238
Tallandoon, tin at..... 1227
Upper Murray, tin from 1232, 1233
Upper Murray River, tin on..... 1236
Upper Yarra, tin in 1229
Wombat Creek, tin lodes at..... 1238
Yarra, *see* Upper Yarra.
See also Australia.
Viebig, W..... 578
Vignon, Leo.....1581, 1582
Villeder, *see* France, Morbihan.
Vilque Chico, *see* Peru.

Reference Number

Vilque district, *see* Peru, Puno.
Vincent, M. C. 1025
Virginia, tin in 1281
Benedict on tin in 1200, 1301
On tin on Irish Creek, Rockbridge County 1239
Blue Ridge, tin in 1241, 1248
Brown on tin on Irish Creek, Rockbridge County 1240
Campbell on tin in the Blue Ridge, Rockbridge County 1241
Capron Springs, tin at 1246
Crookes and Roehrig on tin in 1242
Day on tin in 1203a, 1319
On tin in Rockbridge County 1318
Emmens on tin in 1205
Garrison on tin in 1207
Kemp on tin in 1213
Leonhard on tin in 1214
McCreath and Platt on tin in Rockbridge County 1243
Nelson County, tin at Nellys Ford 1246
R————, on tin in 1218
Robertson on tin on Irish Creek, Rockbridge County 1244
Rockbridge County, tin in 1239, 1240, 1241, 1243, 1244, 1248, 1318
Ulke on Cash mine, near Vesuvius 254, 1245
Vesuvius, Cash mine near 254, 1245, 1246, 1248
Watson on Irish Creek tin locality, Rockbridge County 1246
Winslow on tin in the Blue Ridge, Rockbridge County 1248
See also United States.
Vivian, Joseph 481a
Vlaanderen, C. L. 120, 1647
Vlaklaagte, *see* Transvaal.
Vogelsang 72
Vogt, J. H. L. 1368, 1369, 1370, 1648
Voit, F. W. 3c
Vulcan mine, *see* Queensland, Herberton district.

W

Wada, Tsunashiro 635, 636
Waddington, H. 1152
Wagner, P. A. 235a
Wait, F. W. 482
Walcott, C. D. 35
Walker, Chas. H. 1371
Walker, Edward 482a
Waller, G. A. 1153, 1154-1158
Walsh and Tinaroo field, *see* Queensland.

Reference Number

Waratah, *see* Tasmania.
Ward, L. Keith.....1158a
Ward, L. Keith (Twelvetrees, W. H., and).....1149a
Warmbad, *see* Transvaal.
Warmbaths, *see* Transvaal, Warmbad.
Warner, Richard..... 1421
Warth, H..... 207
Washington, Collier on tin at Silver Hill, near Spokane..... 1250
Silver Hill, tin at..... 1250
Spokane, tin near.....1249, 1250
See also United States.
Waterberg, *see* Transvaal.
Watson, J. Y..... 483
Watson, Thos. L..... 1246
Watsonville, *see* Queensland.
Waukeroo, *see* New South Wales.
Wavellite, de Launay on occurrence in France..... 518
Weaver, Thomas.....608, 609
Webb and Geach..... 484
Webster's workings, *see* Tasmania.
Weed, Walter H..... 1172
Weedon, Thornhill..... 939
Weeks, Joseph D..... 1372
Weinschenk, Ernst..... 578a
Welbeloond, *see* Cape Colony.
Welle Makwa, *see* French Kongo.
Wellington, Wm..... 1159
Wells, J. S. C..... 1583
Wendron, *see* England.
Wendt, A. F..... 184
Werner 1422
West, H. E.....222, 485
Western Australia:
Tin in 45, 1254, 1255, 1290, 1292
Benedict on tin deposits of.....47, 1301
Bridgetown, tin near.....1259, 1271
Coghlan on tin in..... 1679
Gibson (Simpson and) on tin in..... 1269
Greenbushes, tin mines at....1251, 1252, 1253, 1256, 1257, 1260, 1261, 1263, 1264, 1265, 1266, 1267, 1270, 1273
Jackson (Maitland and) on the Greenbushes and Marble Bar (Pilbara) districts..... 1264
Krusch on Greenbushes tin workings..... 1257
On occurrence of tin in..... 1258
Laplage on tin near Bridgetown on the Blackwood River..... 1259

Western Australia—Continued. Reference Number
Maitland on the Greenbushes tin field ... 1260
On the Greenbushes and Pilbara tin fields ... 1261
On the Pilbara tin field ... 1262
On the Wodgina tin field ... 1263
Maitland and Jackson on the Greenbushes and Marble Bar (Pilbara) districts ... 1264
Marble Bar (Pilbara) district, tin in ... 1264
Mulholland on the Greenbushes tin field ... 1265
Newland on output of tin in 1902 and on Greenbushes tin field ... 1266
On tin in ... 1346
Newton on metalliferous minerals of ... 55
Pilbarra, distorted cassiterite crystals from ... 1649
Pilbarra field, tin in ... 1256, 1261, 1262, 1263, 1264, 1271
Simpson on occurrence of cassiterite and stannite ... 1268
On tin ore from Greenbushes field ... 1267
Simpson and Gibson on tin in ... 1269
"Stannifer" on Greenbushes tin field ... 1270
Talbot on Wodgina tin field ... 1271
Wodgina district, tin in ... 1256, 1263, 1271
Woodward on Greenbushes tin field ... 1273
On tin near Bridgetown ... 1272
Woolnough on distorted cassiterite crystals from Pilbarra ... 1649
On tin from Pilbarra ... 1649
See also Australia.
Western district, *see* Queensland.
West Kitty mine, *see* Cornwall.
Weston, E. M. ... 3d, 1583a
West Phœnix mine, *see* Cornwall, Liskeard.
Weyland, A., and Kempen, A. R. (Brandenburg, H., and) ... 1456
Weynek, *see* Transvaal.
Wheal Basset, *see* Cornwall.
Wheal Breage, *see* Cornwall.
Wheal Comfort, *see* Cornwall, Providence mines.
Wheal Kitty, *see* Cornwall.
Wheal Laity, *see* Cornwall, Providence mines.
Wheal Lovell, *see* East Wheal Lovell.
Wheal Prosper, *see* Cornwall.
Wheal Providence, *see* Cornwall, Providence mines.
Wheal Speed, *see* Cornwall, Providence mines.
Wheal Uny, *see* Cornwall.
Wheal Vor, *see* Cornwall.
Wheeler, H. A. ... 1423
White, W. T. ... 486
Whitehead, Edgar ... 1247
White River Bridge, *see* Tasmania.

Reference Number

Whitney, J. D. 223, 1701
Wicksham, F. D. 1160, 1161
Wicklow, *see* Ireland.
Wilber, D. F., *see* No. 1675.
Wildman 308
Wild River, *see* Queensland.
Wilkinson, C. S. 847a-h, 848
Wilkinson, C. S., and David, T. W. E. 849
William, J. Vivian 940
Williams, Archibald 487
Williams, G. W. 940a
Williams, Gerard W. 1161a
Williams, John 488
Williams, R. H. 489, 1668
Williams buddle, Williams on 1668
Willis, Bailey 269a
Wilson, A. P. 1162
Wilson, Geo. 784
Wilson's Downfall, *see* New South Wales.
Winer 1424
Winslow, Arthur 1248
Winslow, *see* Maine.
Wintle, S. H. 1163, 1164
Wirtz, L. 1584
Witmer, Luther Ferree 1585
Wodgina district, *see* Western Australia.
Wodonga district, *see* South Australia.
Wolf, A. G. 231
Wolff, G. 62
Wolfram, *see* wolframite.
Wolframite:
  Andrews on origin of deposits in New South Wales 797
  Associated with tin, *see* Association of tin with.
  Barrow on relation of high level terraces of Bodmin Moor to deposits of stream tin and 333
  Bohemia 64
  Charleton on 1310
  Clotten on occurrence with tin ore in Queensland 898
  Cornwall 1479, 1662
  Cornwall, Bodmin Moor 333
  Dietzsch on treatment of tin-wolfram-copper ores in Cornwall 1479
  Dressing of tin ores containing 1576a, 1664
  France, with tin ore at Ille-et-Vilaine 514
  Kerforne on presence with tin ore at Ille-et-Vilaine, France 514

Wolframite—Continued. Reference Number
Magnetic separator for separating cassiterite and wolframite in Bohemia 64
Malacca, with tin ore in placers..... 682
Metallurgy of..... 1479
New South Wales, accompanying tin ore..... 797
Origin of deposits..... 797
Queensland, accompanying tin ore..... 898
Storms (?) on deposits at Bear Gulch, in tin and gold placers, South Dakota 1015
Separation from tin..... 1662
Skewes on magnetic separation from tin in Cornwall..... 1662
South Dakota..... 1015
Terrell on final stages in dressing of.....1576a, 1664
See also Association of tin with.
Wollastonite, *see* Association of tin with.
Wood, Harrie M..... 850
Wood-tin, Argall on, in Wheal Vor..... 330
Barrosa Cota mine, Bolivia..... 180a
Greg and Lettsom on..... 1614
Headden on, in an old Cornwall furnace..... 1617
Hoffman on, in Klondike River tributaries..... 228
Majendie on occurrence of..... 1342
Pearce on, in an old Cornwall furnace..... 1617
See also 182, 356, 392, 401, 428, 478, 767, 768, 771, 861a, 1156
Woodward, H. P.....1272, 1273
Woodward, John..... 489a
Woods, J. E. T..... 63
Woolnough, W. G..... 1649
Worsey, Jas. P..... 1586
Worth, R. N.....1425, 1426, 1427
Wray, Leonard, Jr.....744, 745, 746, 747
Wright, C. R. Adler..... 1587
Wurtzite, *see* Association of tin with.
Wyborg, *see* Russia.
Wyoming:
Aughey on tin near Rawhide Buttes and in Silver Crown district... 1274
Benedict on tin in..... 1275
Big Horn country, tin in..... 1002
Blake on tin in..... 1202
Chance on tin in the Big Horn country..... 1002
Crook County, tin in.....1016, 1020
Crook County, tin in Black Hills in..... 1276
Day on tin in the Nigger Hill district..... 1318
Guenther on tin in..... 1326
Nigger Hill district, tin in..... 1318

Wyoming—Continued. Reference Number
Rawhide Buttes, tin near ... 1274
Ricketts on tin in Black Hills, Crook County ... 1276
Sadtler on tin in Crook County ... 1016
Silver Crown district, tin in ... 1274
Struthers and Pratt on tin in ... 1220
See also United States and South Dakota.

X

Xaija, *see* Siam.
Xalang, *see* Siam.
Xamphon, *see* Siam.
Xenotime, *see* Association of tin with.
Xeres, *see* Mexico.

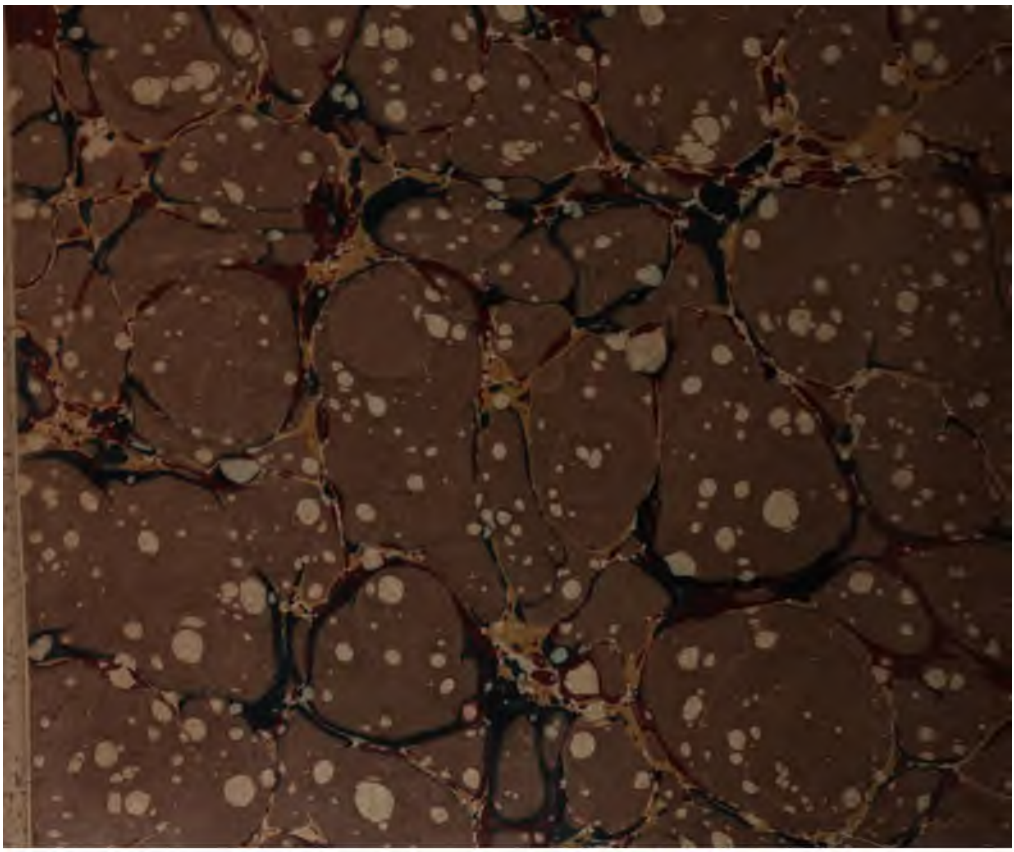
Y

Yarra, *see* Victoria, Upper Yarra.
Yenisei, *see* Jenisei.
York region, *see* Alaska.
Young, G. A. ... 232
Yttrium, *see* Association of tin with.
Yukon, Dawson region, stream tin in ... 23
Hoffman on tin in all the tributaries of the Klondike River ... 228
Yunnan, *see* China.

Z

Zaaiplaats, *see* Transvaal.
Zacatecas, *see* Mexico.
Zamora, *see* Spain.
Zeehan, *see* Tasmania.
Zennor, *see* Cornwall.
Zinc:
Allen on alloy with copper and manganese ... 1431
Alloys with bismuth and tin ... 1587
With copper and manganese ... 1431
With lead and tin ... 1587
Associated with tin, *see* Association of tin with.
Beck on occurrence at Schwarzenberg, Germany ... 530
Bolivia ... 155
British Columbia ... 229
Campagne on mines of ... 1309
Cry of as indication of fitness of certain beams ... 1481
Douglas on metallurgy of ... 1204
Emmons on occurrence in United States and genesis of minerals of ... 1206
Germany, Freiberg ... 560
Germany, Schwartzenberg ... 530
Hydrolysis of salts of, in presence of iodides and iodates ... 1537

Zinc—Continued. Reference Number
Ingalls, Argall, and Garde on zinc resources of British Columbia, and their exploitation ... 229
Ireland ... 602
Kinahan on in Ireland ... 602
Metallurgy of ... 1204, 1549
Moody on hydrolysis of salts of, in presence of iodides and iodates ... 1537
Moore on occurrence with tin in killas of St. Pauls Plains, Tasmania ... 1114
Origin of minerals of ... 1206
Perret on metallurgy of ... 1549
Pilz on deposits in Cartagena, Spain ... 1040
Recovery from scrap tin ... 1584
Richter on characteristics and working, and on relations with tin and lead ... 1356
Saxony, Freiberg ... 560
Slater on alloys of zinc, tin, and lead ... 1570
Spain, Cartagena ... 1040
Sulphides of associated with tin in Bolivia ... 155
Tasmania ... 1114
United States ... 1206
Wirtz on recovery from scrap tin ... 1584
Wright on alloys of lead, tin, and zinc and bismuth, zinc, and tin ... 1587
Zinc-blende, Müller and Richter on tin in at Freiberg, Germany ... 560
See Association of tin with.
Zinc sulphides, *see* Association of tin with.
Zinnwald, *see* Saxony.
Zinnwaldite, *see* Association of tin with.
Zircon, *see* Association of tin with.
Zirkel, Ferdinand ... 490
Zoutpansberg, *see* Transvaal.
Zwartkloof, *see* Transvaal.



v.58
506 Smithsonian miscella
S664m

NAME DATE
Physics Dept. 5/22/13

DOES NOT CIRCULA